Asia-Pacific
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Building Laboratory Capabilities to Assure Water Quality in Asia-Pacific Economies

APEC Sub-Committee on Standards and Conformance

July 2023

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APEC Project: SCSC 01 2021

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1. INTRODUCTION

Water quality is a priority for all economies and underpins food security, agriculture, health, and trade facilitation – all ongoing priorities for the Asia-Pacific Economic Cooperation (APEC). A new "APEC Food Security Roadmap Towards 2030" has been launched as a policy foundation for New Zealand (as 2021 APEC host economy) to support inclusive, resilient and sustainable recovery in the APEC region [1]. Goal 6 of the UN Sustainable Development Goals, states that "availability and access to water, sanitation and hygiene (WASH) services is fundamental" in maintaining public health and in the fight against COVID-19 [2]. The 2021 World Water Development Report on "Valuing Water" also identifies that a solid technical infrastructure is required to obtain good and reliable measurement data to make educated social, economic, and environmental decisions by all levels of governance [3]. The need for traceable measurements supporting water quality policies has also been identified and supported under the European Water Framework [4].

2. OVERALL OBJECTIVES

This project aimed to build laboratories capabilities to measure water quality in Asia-Pacific economies. Experts in the fields of chemical metrology from the Asia Pacific Metrology Programme (APMP), one of the four APEC Specialist Regional Bodies (SRBs), worked with colleagues from the Inter-American Metrology System (SIM) (APMP's counterpart in the Americas) to train laboratory staff to measure parameters affecting water quality and sanitation. The project also ensured cross-SRB cooperation by leveraging the knowledge and expertise of a broad network of stakeholders including member accreditation bodies of the Asia Pacific Accreditation Cooperation (APAC), another of the four APEC SRBs, which accredits testing laboratories working on water quality among other fields. By helping laboratories achieve comparability through internationally recognised measurement frameworks, the project was designed to increase the sustainability of benefits for all economies across the Asia-Pacific region.

3. PROJECT OVERVIEW

The project was structured to commence with a Preparatory Workshop (or **Pre-Measurement Workshop**) organised for staff from measurement institutes and laboratories to share knowledge of the regulatory frameworks in some example APEC economies; to strengthen participants' understanding of core measurement concepts such as analytical measurement techniques, metrological traceability, conformity, and uncertainty of measurement testing and sampling; and to help the participants appreciate the importance of accuracy-based proficiency testing programme (PT) and certified reference materials (CRMs).

This was followed by an accuracy-based PT (**APEC PT**) that provided an opportunity for participating institutes and laboratories to apply their knowledge as well as the training acquired from the Pre-Measurement Workshop, to identify trace elements in

a water matrix and thereby assess and enhance their measurement capabilities. The PT results allowed participants to benchmark their performance with reference values from metrology institutes with relevant Calibration and Measurement Capability (CMC) claims as well as to identify any gaps for future actions.

A **Post-measurement Workshop** was organised to enable APMP and SIM experts to review the results of the APEC PT with participants from developing economies and help address any identified issues. It also provided the opportunity for participants to share their experiences in undertaking the measurements, to identify further needs and to develop action plans for future strategies to improve laboratory practices and measurement capabilities.

Altogether, the project was designed to provide a sound foundation from which economies could further build their capabilities in water quality measurement and testing as needed to address emerging priorities and ensure their ongoing relevance and sustainability. The project provided a capacity building framework that enabled participants to achieve global comparability of performance via established accreditation and measurement frameworks.

4. PRE-MEASUREMENT WORKSHOP

4.1 ORGANISATION OF PRE-MEASUREMENT WORKSHOP

The Pre-Measurement Workshop, sponsored by Australia and co-sponsored by Canada; China; Hong Kong, China; and Singapore, was organised on 23 - 24 March 2022 (1:30 to 4:00 UTC). The virtual workshop brought together experts from water agencies of two APEC economies, metrology institutes from APMP and SIM, as well as APAC to discuss key metrics of water quality data.

The workshop was organised by a committee comprising:

- Dr Angela Samuel, National Measurement Institute, Australia (NMIA)
- Professor Zoltan Mester, National Research Council, Canada (NRC)
- Dr Tang Lin Teo, Health Sciences Authority, Singapore (HSA)
- Dr Della Sin, Government Laboratory, Hong Kong, China (GLHK)
- Professor Ping He, China National Accreditation Service for Conformity Assessment, China (CNAS)
- Professor Hongmei Li, National Institute of Metrology, China (NIM)
- Professor Liandi Ma, National Institute of Metrology, China (NIM)
- Mr Paul McMullen, National Association of Testing Authorities, Australia (NATA)

Presentations from technical experts in inorganic analysis were aimed at helping participants deal with potential challenges in the measurement of trace elements in water and improve their measurement capabilities ahead of their participation in the APEC PT that followed the workshop.

The workshop was organised in two sessions. The first session covered overviews of the water quality regulatory frameworks in some example APEC economies and the standard methods applied by water agencies for water monitoring. It also emphasized

the importance of CRMs and their availability from metrology institutes in the Asia-Pacific and American regions. The value of accuracy-based PTs as compared to consensus-based PTs was also highlighted. This session was organised to benefit Managers, Technical/Quality Managers and personnel in technical supervisory roles.

The second session covered core measurement concepts, including analytical measurement techniques, uncertainty of measurement testing and sampling. This session also included presentations from inorganic analysis experts to help participants in the APEC PT. This session was organised to benefit Technical Managers, Scientists and Technical Professionals involved in front-line measurements. See Annex A for the Programme Booklet with the full workshop programme and speakers' biographies.

4.2 KEY OUTCOMES OF PRE-WORKSHOP SURVEY

To better understand the background of the participants, a pre-workshop survey (using FORMSG electronic form[1] - See Annex B) was sent alongside the Programme Booklet and registration instructions in an email announcement. A total of 170 individuals responded to the survey, of whom 70.6% (120 out of 170) were from APEC economies. The outcomes of the pre-workshop survey are shown in Annex B.

To summarise the outcomes of the pre-workshop survey, majority of the respondents are accredited for water testing and/or plan to seek accreditation or extend their accreditation scope to cover more areas of water testing. Inorganic analytes were identified as the top parameters in which respondents intend to apply or extend their accreditation scope. Majority of the respondents also expressed their intent to participate in the APEC PT covering arsenic (As), cadmium (Cd), lead (Pb) and antimony (Sb) in natural mineral water.

4.3 PARTICIPATION IN PRE-MEASUREMENT WORKSHOP

The virtual workshop was hosted using the Zoom Webinar platform. There were slightly over 220 attendees[2] on both days. Participant APEC economies were: Australia; Brunei Darussalam; China; Hong Kong, China; Indonesia; Republic of Korea; Malaysia; Mexico; New Zealand; Peru; the Philippines; Singapore; Chinese Taipei; United States; and Viet Nam. One speaker and a member of the Organising Committee/Session Chair were from Canada. Hence, 76.2% (16 out of 21) of APEC's member economies were involved in the workshop. See Figure 1 showing the

[1] FormSG is a form builder tool developed by the Data Science & Artificial Intelligence Capability Centre of Singapore's Government Technology Agency. FormSG enables public officers to create digital government forms in minutes, replacing the use of paper forms.

[2] The number of attendees as recorded by Zoom did not include individuals who only listened by phone or multiple persons who shared a single device. Viewers who joined the webinar multiple times or from multiple devices were only counted once. The numbers also excluded the Session Chair and Panelist who were Speakers and/or Organising Committee members (refer to Annex A).

geographical spread of attendees from APEC economies only. More than 60% of the attendees were female at the first and second sessions of the workshop.

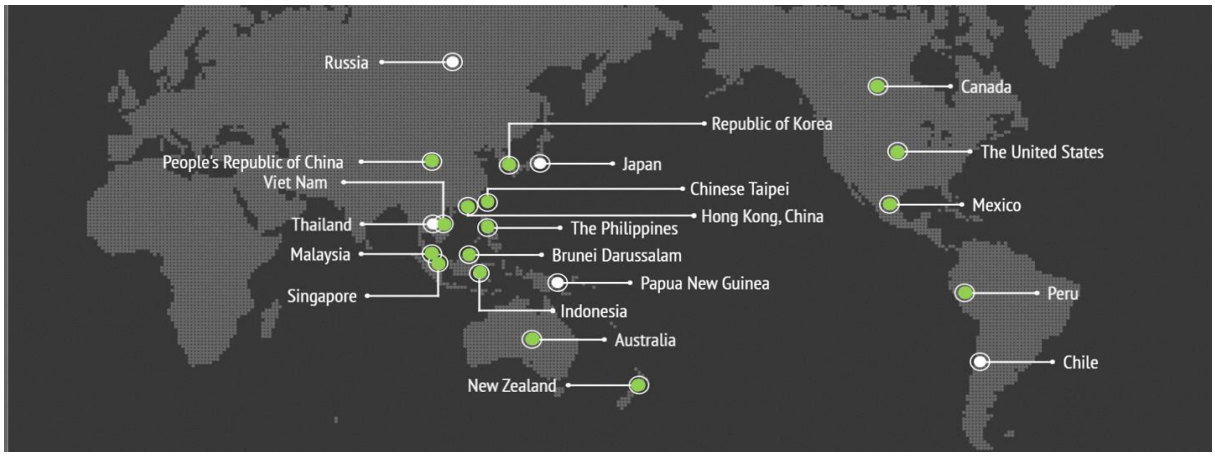


Figure 1: The green dots show the locations of the workshop attendees/speakers from APEC economies only.

During the workshop, the Session Chairs posted "live" questions to the audience using the platform's poll function. The outcomes of the online polls are shown in Annex C.

To summarise the outcomes of the online polls, the attendees mostly come from laboratories that provide testing services, research & development and quality assurance. One of the key messages that the committee tried to deliver was the value of accuracy-based PTs as compared to consensus-based PTs. It was encouraging to note that after the presentation, the majority of the attendees expressed a preference to participate in an accuracy-based PT. Though accuracy-based PTs are often more resource-demanding for the PT organiser(s), they are less prone to biased assessment of PT results and wrong policy decisions regarding participants' measurement capabilities.

4.4 KEY OUTCOMES OF POST-WORKSHOP SURVEY

With the aim of improving the quality of the APEC project and planning the next steps, the Organisers sought feedback from the attendees through a post-workshop survey (using FORMSG electronic form – See Annex D) sent out 6 hours after the workshop. There were 187 respondents, i.e., over 80% of the attendees of the workshop provided feedback. Of these, 81.8% (153 out of 187) were from APEC economies. The outcomes of the post-workshop survey are shown in Annex D.

To highlight the outcomes of the post-workshop survey, more than 90.9% of the respondents found the Workshop topics to be mostly or very relevant to themselves or their economies. Between 89.3% and 98.9% of the attendees agreed or strongly agreed that the objectives of the workshop were clearly defined, well covered and achieved its intended objectives; the speakers had provided sufficient materials and they were well prepared and knowledgeable; the workshop was well-paced; and the selected platform was user-friendly and allowed interactions with the speakers.

5. APEC PT ON TRACE ELEMENTS IN NATURAL WATER (APEC PT 2022)

5.1 ORGANISATION OF APEC PT 2022

APEC PT 2022 – "Trace Elements in Natural Water" was organised by GLHK in accordance with the requirements of ISO/IEC 17043:2010 [5]. This PT covered the determination of four elements, namely Arsenic (As), Cadmium (Cd), Antimony (Sb) and Lead (Pb) in natural water. The objectives were to support the participating laboratories in demonstrating their competenc(i)es in the measurement of mass fractions of the analytes in the natural water sample by various analytical techniques; and to identify any issue(s) and opportunities for improvement.

GLHK was responsible for all tasks in the development and operation of this PT, including preparation and distribution of PT samples, data analysis and evaluation of results, preparation of interim and final reports, and communications with participants.

The PT material was prepared from commercially available bottled natural mineral water from Fanjing Mountain, World Natural Heritage, China. The PT material was spiked with the analytes of interest and stabilised using 2% nitric acid. The material was homogenised, packaged into pre-cleaned amber HDPE bottles and sealed inside aluminized Mylar pouches. About 180 bottles were prepared and stored at 4°C. Each bottle contains at least 200mL of sample solution. The expected mass fraction of the four analytes was between 0.1 to 30µg/kg. The homogeneity and stability studies were performed in accordance with ISO 13528:2015 [6]. The PT samples were shown to be sufficiently homogeneous and adequately stable.

In May 2022, each registered participant was provided with one bottle of PT sample. Relevant documents including the "Protocol", "Sample Receipt Form" and "Result Proforma" were sent via e-mail at the time of distribution of the PT samples (See Annexes E, F and G). Upon receipt of the PT sample, participants were requested to promptly check the physical conditions and return the "Sample Receipt Form" via e-mail. GLHK did not receive any report pertaining to lost or damaged samples. Participants were required to complete the Result Proforma and to report the mass fraction of each analyte in µg/kg, derived from the average of at least 3 independent measurements, with its associated uncertainty as well as information about the methods used for analysis. To allow participants to check for transcription errors, if any, made unintentionally by the PT provider, the Interim Report was issued in December 2022. The Final Report was issued in early May 2023, providing a comprehensive overview of participants' results and detailed discussions of their methods of analysis.

5.2 PARTICIPATION IN APEC PT 2022

A total of 64 laboratories from 23 economies registered in the APEC PT 2022 and 54 of them returned the Result Proforma on or before the deadline of 30 September 2022. See Table 1 for the summary of participation in the APEC PT 2022. For the determination of As, Cd, Sb and Pb, 51, 53, 41 and 53 laboratories submitted results, respectively. See Table 2 for the geographical distribution of PT participants. Each

participant was assigned a unique laboratory code and the code was used throughout the PT scheme for identification purpose. Information related to a particular participant's performance will not be disclosed to any third party unless prior agreement with the participant(s) has been obtained or applicable laws or regulations stipulate such disclosure.

Table 1: Summary of participation in APEC PT 2022.

Total registered participants	64
PT sample successfully delivered	60
PT sample not dispatched*	4
Submitted results	54
Unable to submit results	2
No response	4

** No courier service was available to deliver the samples to Russian laboratories up to the deadline of result submission.*

Table 2: Geographical distribution of PT participants.

No.	**Economies** Note 1	**Participants Registered (APEC member)**	**Participants Registered (Non-APEC member)**	**Returned Results**	**Returned Results (As)**	**Returned Results (Cd)**	**Returned Results (Sb)**	**Returned Results (Pb)**
1	*Bangladesh	-	1	1	1	1	1	1
2	Brunei Darussalam	2	0	2	1	2	0	2
3	Canada	2	0	2	2	2	2	2
4	Chile	2	0	1	1	1	1	1
5	*Ecuador	-	1	1	1	1	1	1
6	Hong Kong, China	1	1	2	2	2	2	2
7	*India	-	2	2	2	2	1	2
8	Indonesia	0	2	2	1	2	0	2
9	Japan	0	3	3	3	3	2	3
10	Mexico	0	1	1	1	1	1	1
11	*Mongolia	-	2	2	1	2	1	2
12	*Nepal	-	1	0	0	0	0	0

No.	Economies Note 1	Participants Registered (APEC member)	Participants Registered (Non-APEC member)	Returned Results	Returned Results (As)	Returned Results (Cd)	Returned Results (Sb)	Returned Results (Pb)
13	New Zealand	0	2	2	2	2	2	2
14	*Pakistan	-	2	2	2	2	1	2
15	The Philippines	1	5	5	5	4	3	4
16	The Russian Federation Note 2	0	4	0	0	0	0	0
17	*Saudi Arabia	-	4	4	4	4	4	4
18	Singapore	1	4	5	5	5	5	5
19	Chinese Taipei	0	2	2	2	2	2	2
20	*Sri Lanka	-	2	2	2	2	2	2
21	Thailand	4	2	6	6	6	5	6
22	United States	0	5	3	3	3	2	3
23	Viet Nam	1	4	4	4	4	3	4
	Total	**14**	**50**	**54**	**51**	**53**	**41**	**53**

*Note 1: According to the economy of the accreditation body, and symbol * denotes non-APEC member.*

Note 2: No courier service was available to deliver the samples to Russian laboratories until the deadline of result submission.

5.3 ASSIGNMENT OF METROLOGICALLY TRACEABLE REFERENCE VALUES

The reference values provided by up to five metrology institutes with relevant Calibration and Measurement Capability (CMC) claims (including GLHK, HSA, NIM, NMIA and NRC) were used as the assigned values for evaluating the performance of participants in this PT scheme [7]. The provision of reference values employed high accuracy methods such as isotope dilution mass spectrometry (IDMS) or gravimetric standard additions. These assigned values are traceable to the International System of Units (SI). See Table 3 for list of analytes with their assigned values and associated expanded uncertainties.

Table 3: List of analytes with their assigned values and associated expanded uncertainties.

Analyte	Assigned value (µg/kg)	Expanded uncertainty, *U* (µg/kg)	Relative *U*
As	8.95	0.12	1.4%
Cd	2.399	0.029	1.2%
Sb	4.24	0.11	2.5%
Pb	12.74	0.11	0.9%

5.4 PERFORMANCE EVALUATION

The performance of the participating laboratories was primarily evaluated by z-scores. The standard deviation for proficiency assessment (σ_{pt}) was derived from the Horwitz Equation [8]. ζ-Scores (when measurement uncertainty was reported) was evaluated as supplementary information. See Table X for distribution of z-scores and ζ-scores.

The *z*-score of each participating laboratory's result was calculated according to Equation 1 below:

$$z_i = \frac{x_i - x_{pt}}{\sigma_{pt}} \quad \text{— (1)}$$

where z_i is *z*-score of the participating laboratory
x_i is the participating laboratory's result
x_{pt} is the assigned value
σ_{pt} is the standard deviation for proficiency assessment

As evaluation of measurement uncertainty is one of the important technical requirements of ISO/IEC 17025:2017 [9], the ζ-score was also evaluated, complementary to the *z*-score in the assessment of a participating laboratory's performance. The ζ-score takes the standard measurement uncertainty reported by the participating laboratory into consideration and was calculated according to Equation 2.

$$\zeta_i = \frac{x_i - x_{pt}}{\sqrt{u^2(x_i) + u^2(x_{pt})}} \quad \text{— (2)}$$

where ζ_i is ζ-score of the participating laboratory
x_i is the participating laboratory's result
x_{pt} is the assigned value
$u(x_i)$ is the standard uncertainty reported by the participating laboratory
$u(x_{pt})$ is the standard uncertainty of the assigned value x_{pt}

A *z*-score or ζ-score with absolute value of:

$\|z\|$ or $\|\zeta\| \leq 2.0$	implies "satisfactory" result
$2.0 < \|z\|$ or $\|\zeta\| < 3.0$	implies "questionable" result
$\|z\|$ or $\|\zeta\| \geq 3.0$	implies "unsatisfactory" result

5.5 OUTCOMES OF APEC PT 2022

Table 4 shows the distribution of z-scores and ζ-scores of the participants.

Table 4: Distribution of z-scores and ζ-scores.

	z-Score Number of Participants (Percentage)				**ζ-Score Number of Participants (Percentage)**			
	As	**Cd**	**Sb**	**Pb**	**As**	**Cd**	**Sb**	**Pb**
$\|z\|$ or $\|\zeta\| \leq 2.0$	47 (92%)	45 (87%)	33 (83%)	48 (91%)	21 (49%)	21 (48%)	11 (33%)	21 (47%)
$2.0 < \|z\|$ or $\|\zeta\| < 3.0$	1 (2%)	0 (0%)	2 (5%)	2 (4%)	1 (2%)	5 (11%)	4 (12%)	5 (11%)
$\|z\|$ or $\|\zeta\| \geq 3.0$	3 (6%)	7 (13%)	5 (13%)	3 (6%)	21 (49%)	18 (41%)	18 (55%)	19 (42%)
Total:	51	52	40	53	43	44	33	45

Note: The percentages may not add up to 100% due to rounding up of figures to the nearest digit.

Participants with $|z| \geq 3.0$ were advised to thoroughly investigate their results. Participants with z-scores in the range of $2.0 < |z| < 3.0$ were also encouraged to review their results. If a laboratory obtained $|z| \geq 3.0$, it was recommended to examine the test procedure step-by-step and to derive an uncertainty budget for that procedure in order to identify the steps from which the largest uncertainties arose. The laboratory could spend more efforts on these steps to achieve improvements. If the laboratory also attained $|\zeta| \geq 3.0$, it implies that the uncertainty budget might not include all significant sources of uncertainty and required further evaluation.

More than 80% of participants reported their measurement uncertainties. However, it was noted that some of the reported measurement uncertainties were underestimated or overestimated (e.g., reporting a relative expanded uncertainty of as small as 0.05% or as large as 450% in extreme cases). As illustrated by the distribution of ζ-scores shown in Table 4 (provided only for reference and not being used to evaluate performance in the APEC PT), further capacity building efforts with respect to evaluation of measurement uncertainty should be useful for participants who had difficulties in reporting measurement uncertainty.

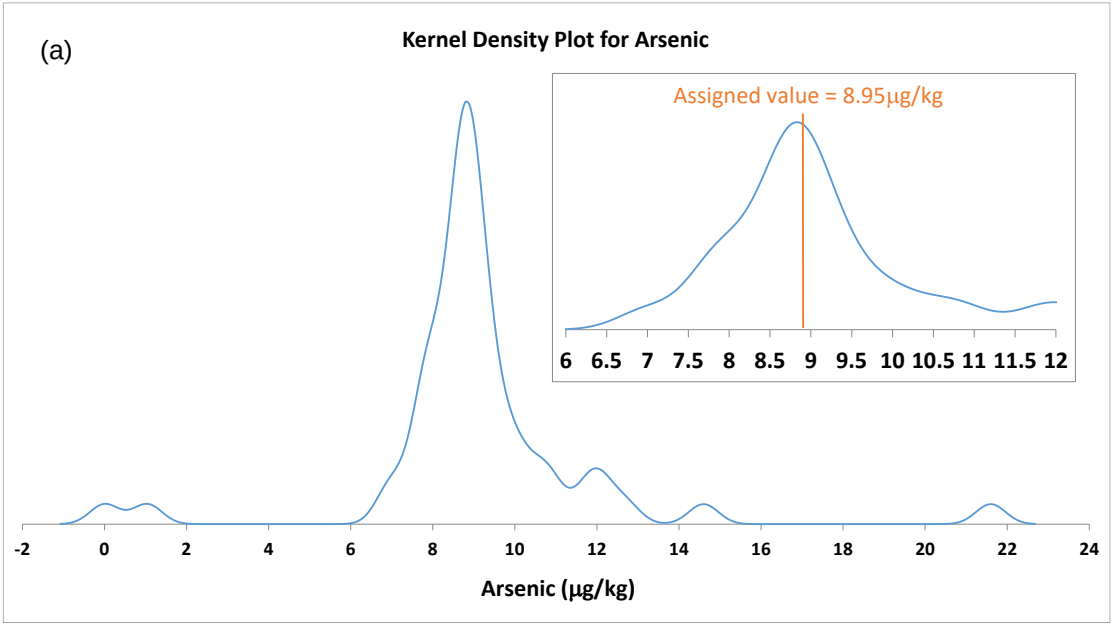
The robust averages of the participants' results were calculated in accordance with Algorithm A in ISO 13528:2015 [6]. The results considered as blunders (deviated from the assigned values by about 3 orders of magnitude) were not included in the robust statistics. See Table 5 for the comparison between the assigned values and robust averages. The robust averages of all analytes were found to be close to the assigned

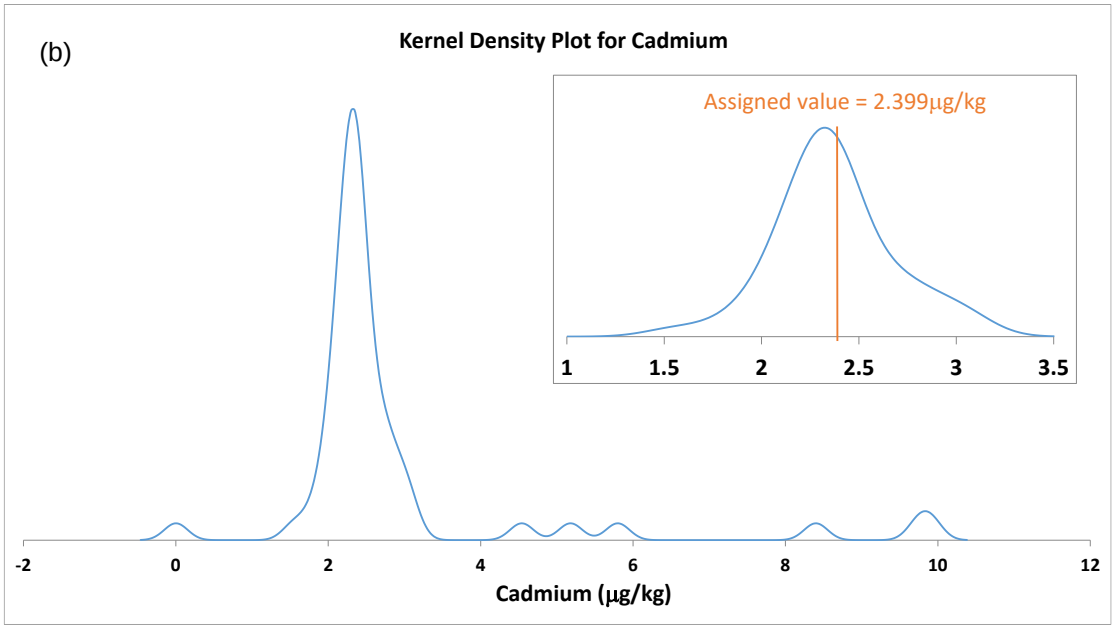
values. The relative deviations range from –4.4% to 2.9%, which are considered small compared to the relative σ_{PT} of 22%.

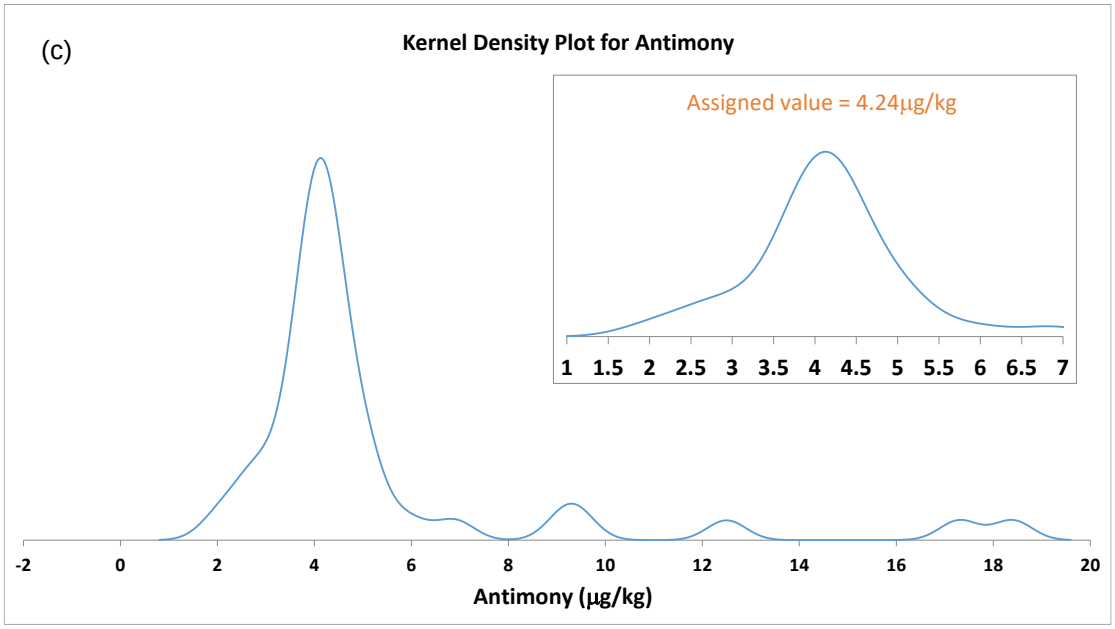
Table 5: Comparison between the assigned values and robust averages.

	As	Cd	Sb	Pb
Assigned value (µg/kg)	8.95	2.399	4.24	12.74
σ_{PT} (µg/kg)	1.97	0.528	0.93	2.80
Robust average (µg/kg)	9.05	2.45	4.36	12.2
Deviation (µg/kg)	0.10	0.042	0.12	–0.56
Deviation (%)	0.7	2.3	2.9	–4.4

For reference purpose, the kernel density plots derived from the participants' results are provided in Figure 2. The plots were generated by MS Excel Add-in software which could be freely downloaded from the website of the Royal Society of Chemistry [10]. The kernel density estimator is a useful method of representing the overall structure of the participants' results. The most prominent modes of As, Cd, Sb and Pb were 8.99, 2.345, 4.18 and 12.33µg/kg, respectively, which were close to the corresponding assigned values.




(b)
Kernel Density Plot for Cadmium
Assigned value = 2.399µg/kg
1
1.5
2
2.5
3
3.5
-2
0
2
4
6
8
10
12
Cadmium (µg/kg)


(c)
Kernel Density Plot for Antimony
Assigned value = 4.24µg/kg
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
-2
0
2
4
6
8
10
12
14
16
18
20
Antimony (µg/kg)

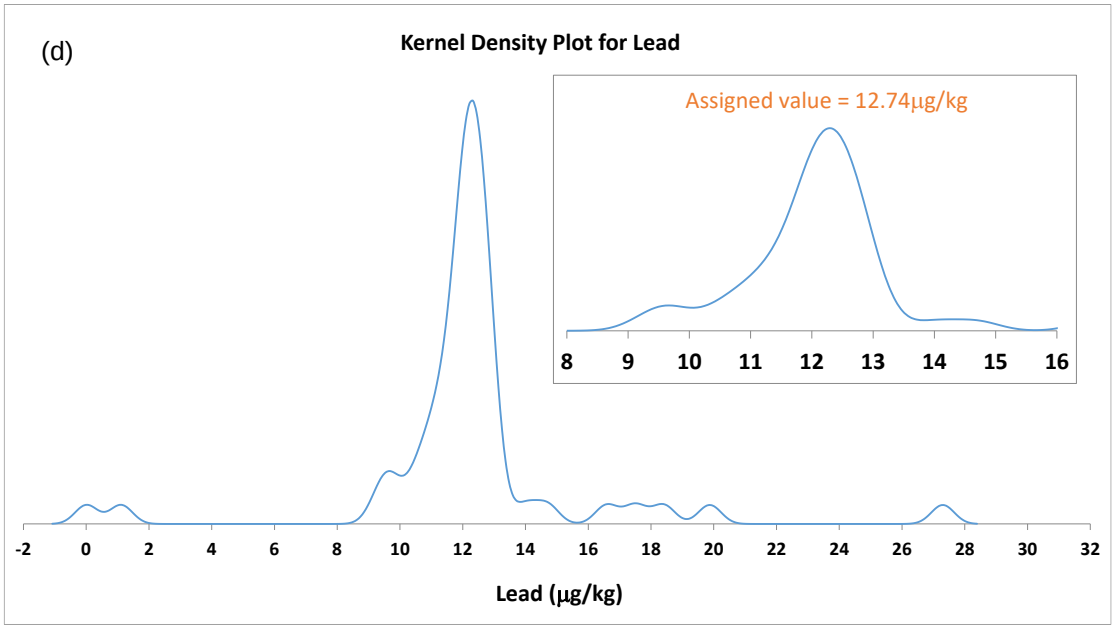
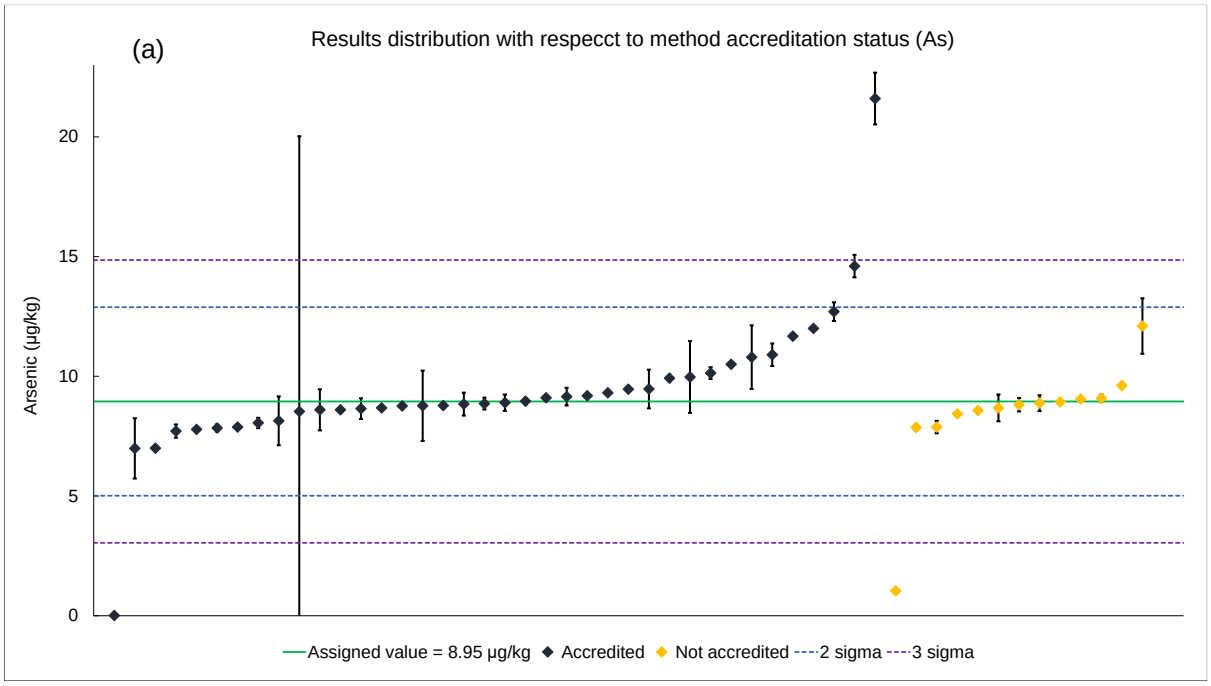
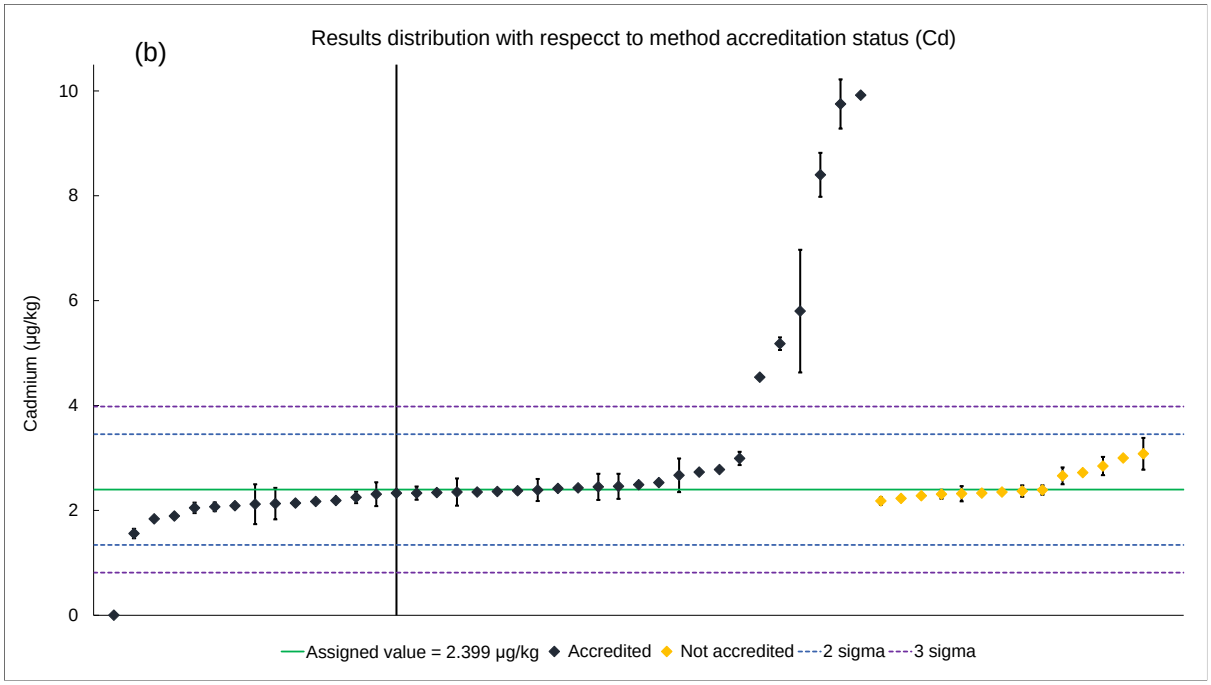
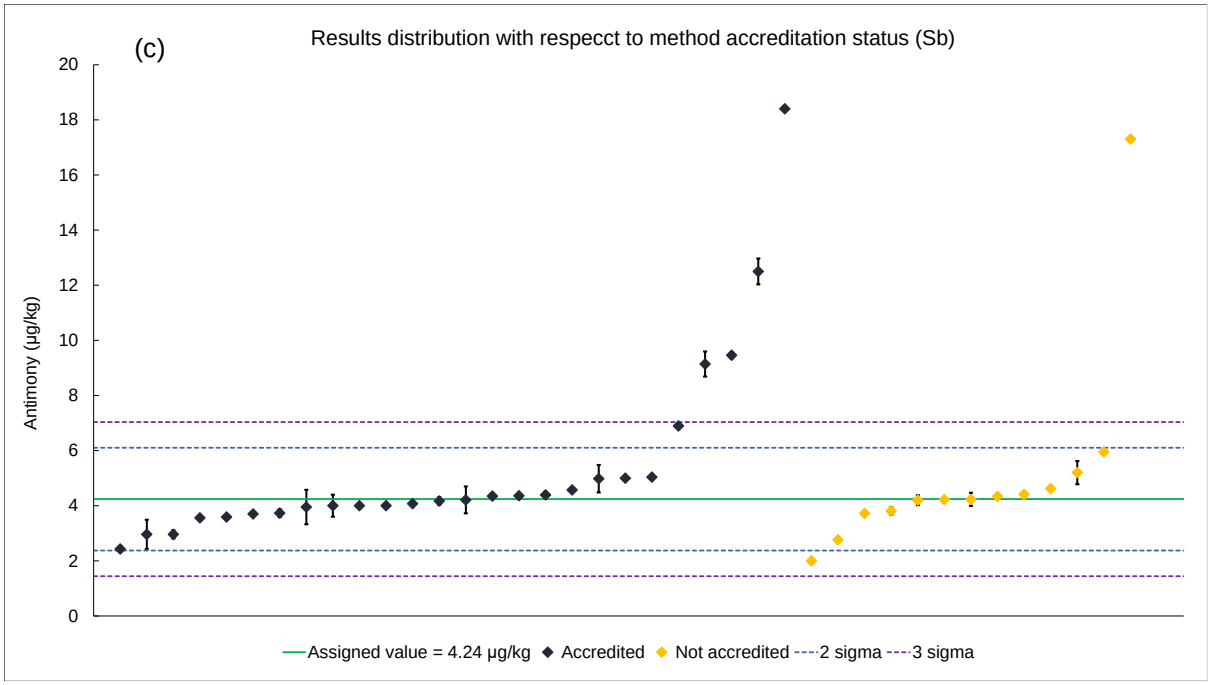


Figure 2: Kernel density plots derived from the participants' results for As (a), Cd (b), Sb (c) and Pb (d).

Most of the participants employed accredited method(s) for the analysis. See Figure 3 for the plots of participants' results with respect to the method accreditation status. No obvious correlation between method accreditation status and performance was observed for As, Sb and Pb. However, participants that used non-accredited methods seemed to demonstrate better performance than those that used accredited methods for measurement of Cd.




(b)
Results distribution with respecct to method accreditation status (Cd)
Cadmium (µg/kg)
0
2
4
6
8
10
Assigned value = 2.399 µg/kg
Accredited
Not accredited
2 sigma
3 sigma


(c)
Results distribution with respecct to method accreditation status (Sb)
Antimony (µg/kg)
0
2
4
6
8
10
12
14
16
18
20
Assigned value = 4.24 µg/kg
Accredited
Not accredited
2 sigma
3 sigma

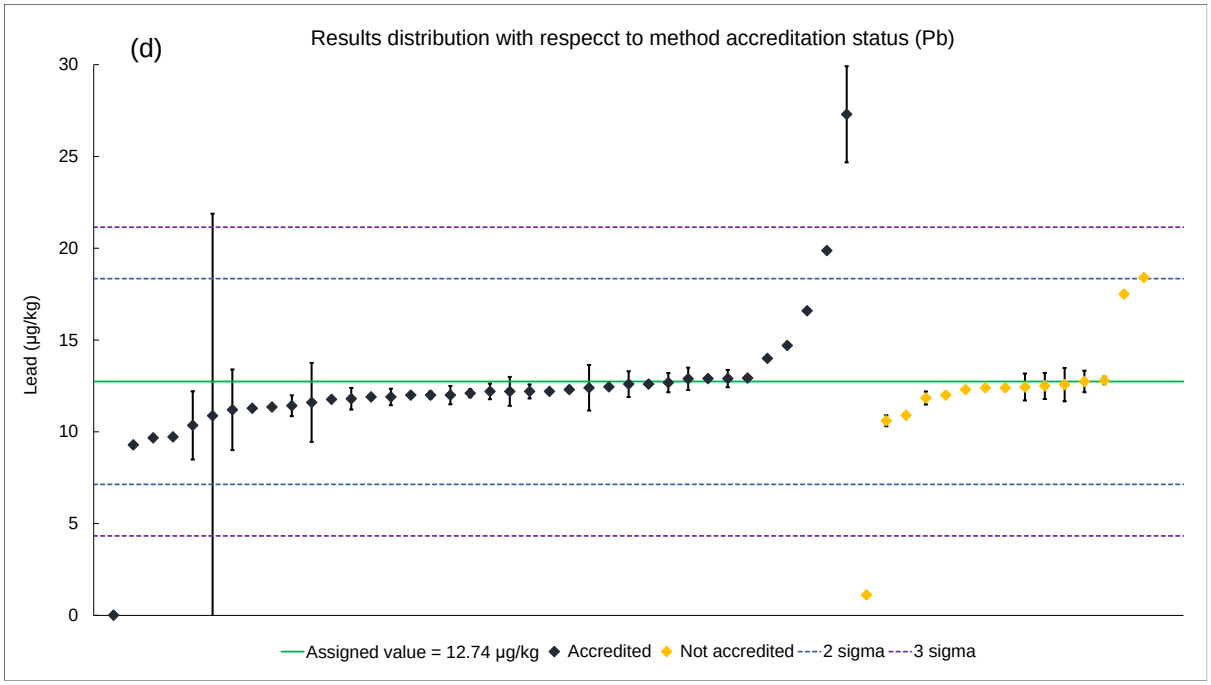
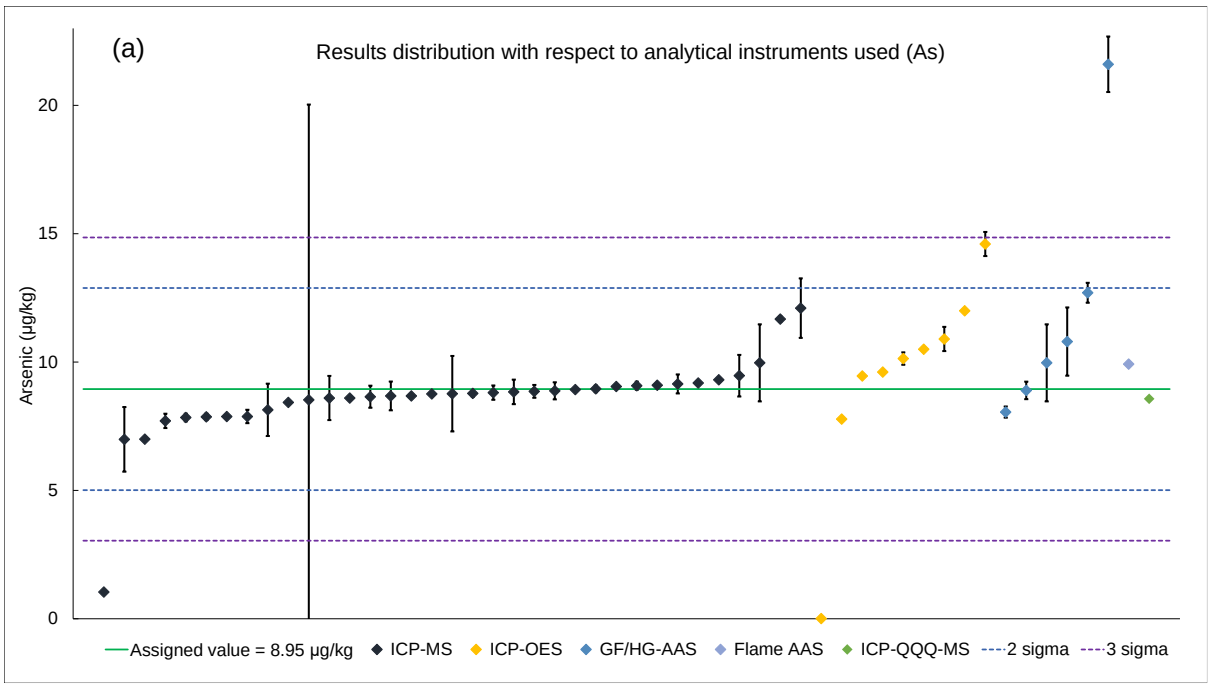
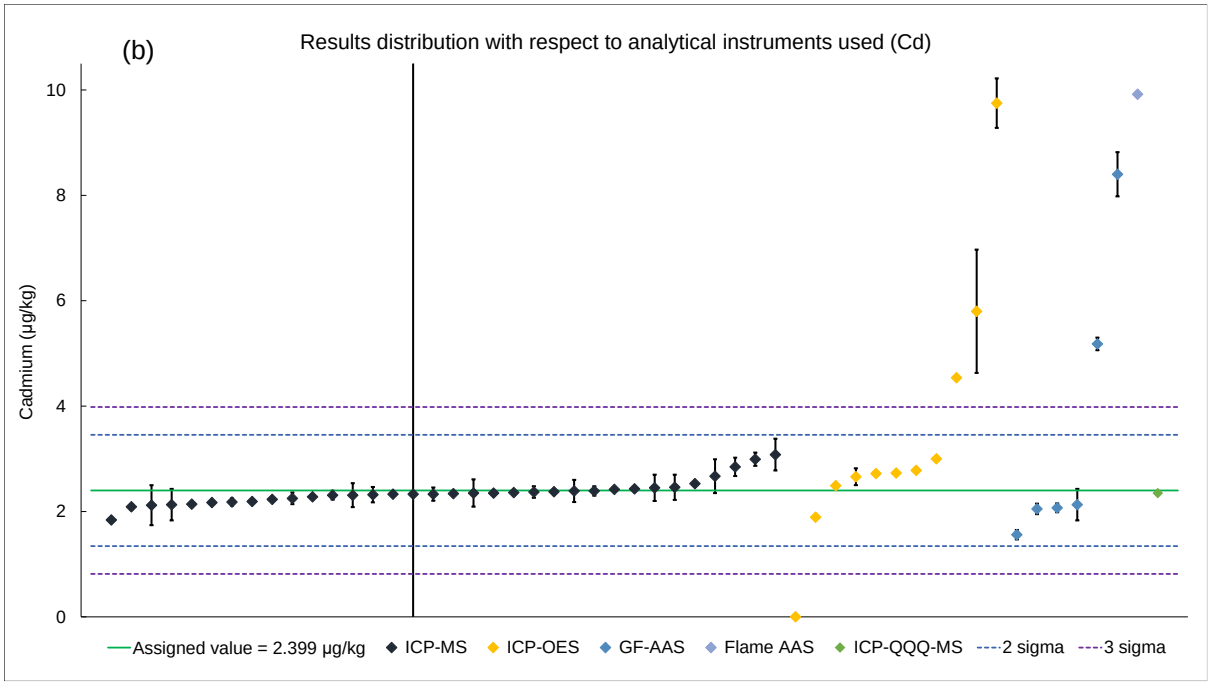
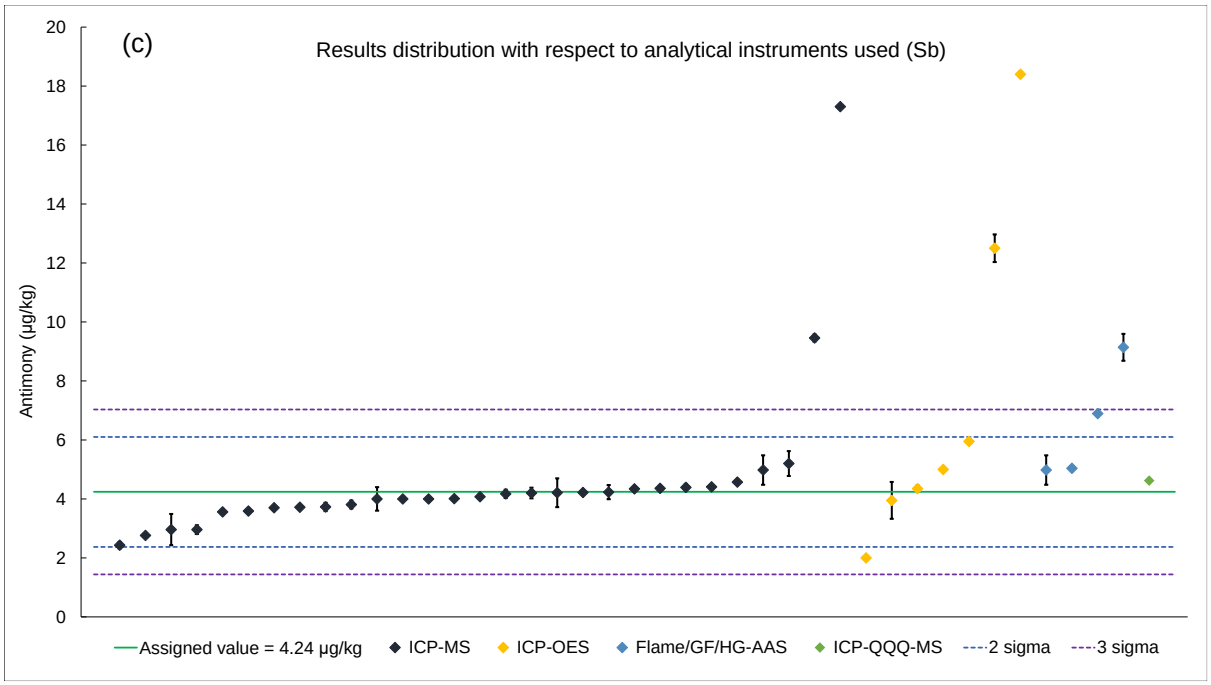


Figure 3: Participants' results with respect to the method accreditation status for As (a), Cd (b), Sb (c) and Pb (d).

Most PT participants used ICP-MS for analysis. Other instruments used included ICP-OES and AAS. See Figure 4 for the plots of participants' results with respect to the analytical instruments. The participants that used ICP-MS showed better agreements with the assigned values as compared to other instruments.




(b)
Results distribution with respect to analytical instruments used (Cd)
Cadmium (µg/kg)
0
2
4
6
8
10
Assigned value = 2.399 µg/kg
ICP-MS
ICP-OES
GF-AAS
Flame AAS
ICP-QQQ-MS
2 sigma
3 sigma


(c)
Results distribution with respect to analytical instruments used (Sb)
Antimony (µg/kg)
0
2
4
6
8
10
12
14
16
18
20
Assigned value = 4.24 µg/kg
ICP-MS
ICP-OES
Flame/GF/HG-AAS
ICP-QQQ-MS
2 sigma
3 sigma

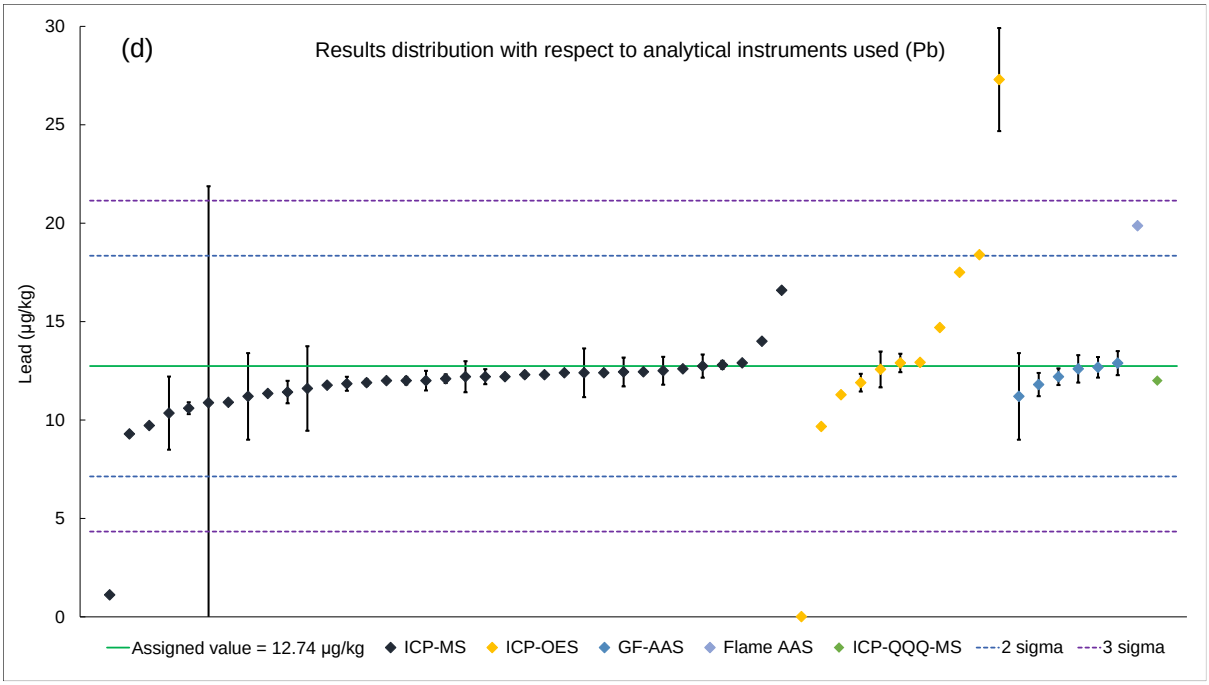


Figure 4: Participants' results with respect to the analytical instruments for As (a), Cd (b), Sb (c) and Pb (d).

The reported recoveries of matrix CRMs or quality control samples were generally good, mostly in the range of 90–110%. The majority of participants did not perform correction of recovery. The use of a suitable matrix CRM or an in-house spiked material (if the former is not available) as a quality control sample to check on method recovery is strongly encouraged in routine analysis.

5.6 FEEDBACK

Feedback and comments were sought from participating laboratories through a pre-workshop survey for the Post-Measurement Workshop (using FORMSG electronic form - See Annex I). The following responses were received *(in verbatim)*.

- It is a pleasure that we have been invited to participate in this project, it is a new experience and a great opportunity to share experiences and knowledge with other laboratories.
- Joining the APEC PT on "Trace Elements in Natural Water" is a good opportunity to learn new knowledge from leading experts, helping us to improve our capacity in the field of water testing, as well as experience in value assignment and RM/CRM production. I hope that APAC will organize more events in the near future.
- The time frame taken for conducting the PT Programme is very large. Also complete workshop shall be conducted in Online/Offline modes considering the pandemic period. Communication part from the organiser is very good.

- There has been no feedback regarding the results of the participation, so generally a pre-report is sent to the participants before attending the results evaluation meeting. The foregoing serves as input for quality systems and monitoring of participation in proficiency tests.
- APEC PT on "Trace Elements in Natural Water" is good to assess the performance of laboratories for the analysis Pb, Cd, As and Sb using different analytical techniques and is a mode of EQA. The scheme is well planned and managed and very smoothly conducted.
- APEC PT on "Trace Elements in Natural Water" was very well-organized. There was effective communication between PT provider and the participants.
- Please provide more sample, it possible.
- Suggestion to include the z-score of the submitted results.
- Faster release of report.
- Yes, at first it was difficult for me to understand the instructions, I hope they consider sending them in Spanish so that the translation that one makes does not affect the correct execution of the test material. *(Note: translated using Google translate)*

6. POST-MEASUREMENT WORKSHOP

6.1 ORGANISATION OF POST-MEASUREMENT WORKSHOP

As the final stage of the project, the Post-Measurement Workshop was organised to review results from the APEC PT, as well as two parallel studies organised for the metrology community: the APMP pilot study APMP.QM-P41 and the SIM Supplementary Comparison SIM.QM-S12. The Workshop was supported by APEC, APMP's DEC and CWFG, SIM, APAC and PTB.

The Workshop Organising Committee comprised:

- Dr Teo Tang Lin (HSA)
- Dr Angela Samuel (NMIA)
- Dr Della Sin (GLHK)
- Dr Shima Hashim, Department of Chemistry, Malaysia (KIMIA)
- Prof Liandi Ma (NIM)
- Prof Zoltan Mester (NRC)
- Mr Ping He (CNAS)
- Mr Paul McMullen (NATA)
- Dr Samuel Cheung (GLHK)
- Dr Fransiska Dewi (HSA)

The Workshop was held in Kuala Lumpur, Malaysia from 6 - 9 March 2023 and hosted by KIMIA. The Workshop objectives were to provide a forum to discuss the outcomes from the measurements undertaken by participating institutes/laboratories in the three measurement activities, identify capability and knowledge gaps, share requirements and applications of relevant international standards, and propose action plans for future strategies to improve laboratory practices, measurement capabilities and quality

infrastructure. See Annex H for the Programme Booklet with the full workshop programme and speakers' biographies.

6.2 KEY OUTCOMES OF PRE-WORKSHOP SURVEY

To better understand the background of the participants, a pre-workshop survey (using FORMSG electronic form - See Annex I) was sent to all eligible registrants (both in-person and online). A total of 57 individuals from 40 institutes in 25 economies responded to the survey, of whom 56.1% (32 out of 57) were from APEC economies. The outcomes of the pre-workshop survey are shown in Annex I.

A few key outcomes to highlight from the pre-workshop survey include the large percentage of respondents (73.7%) that sharing their plans to seek accreditation or extend their accreditation scopes and that inorganic parameters were identified as the top parameters. The majority of the respondents, 88.2% stated that their participation in the APEC PT had provided evidence to support their institute/laboratory's accreditation status. Some of the respondents that participated in the APEC PT had provided feedback through the pre-workshop survey, which can be found in Section 5.6.

6.3 PARTICIPATION IN POST-MEASUREMENT WORKSHOP

Invited speakers came from metrology institutes [Organising Committee institutes and the Korea Research Institute of Standards and Science (KRISS)]; standards & conformance bodies [those included on the Organising Committee as well as the National Accreditation Board for Testing & Calibration Laboratories (NABL), India, and the Standards Council of Canada (SCC)]; and a regulatory body (Health Canada).

The first two days of the Workshop were conducted in hybrid format followed by a 2-day onsite workshop involving 36 experts/participants attending in-person and about 40 attendees online from most APEC economies as well as APMP and SIM member/associate member economies. Participants included representatives from metrology institutes, accreditation bodies, as well as testing laboratories in public and private entities from 29 economies.

Participants came from most APEC economies, including Australia; Brunei Darussalam; Canada; Chile; People's Republic of China; Hong Kong, China; Indonesia; Republic of Korea; Malaysia; Mexico; Peru; the Philippines; Singapore; Chinese Taipei; Thailand; and Viet Nam (numbered from 1-16). In addition, participants from non-APEC economies joined the Workshop, including from Bangladesh, Bolivia, Brazil, Cambodia, Costa Rica, Egypt, India, Kenya, Mongolia, Nepal, Oman, Pakistan, and Sri Lanka (numbered from 17-29). See Figure 5.

Figure 5: The numbers show the locations of the workshop attendees/speakers.

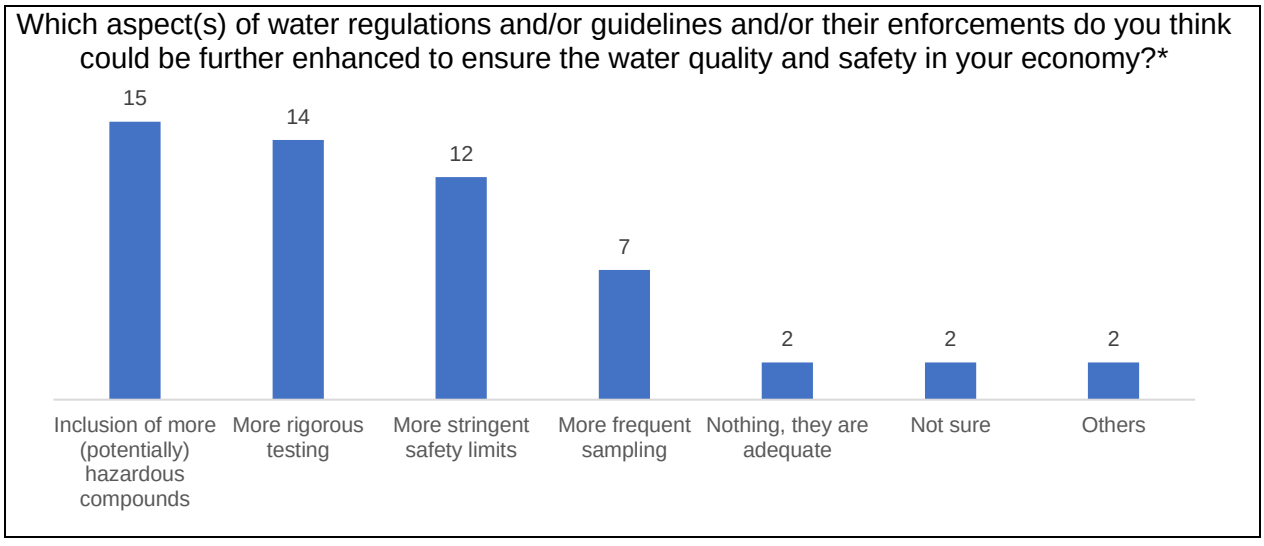
The theme for the first day of the Workshop was Implementing a Quality Management System for Water Testing. A series of presentations were provided by experts on the importance of quality infrastructure in ensuring water quality and the importance of accuracy-based PT programmes. The organisation and outcomes of the APEC Water PT were also presented. The second day focused on the lessons learned from the APEC Water PT. A total of 19 attendees who participated in the PT or the parallel APMP.QM-P41 and SIM.QM-S12 shared the approaches that they used during the study, the challenges encountered as well as their future plans. A panel discussion session was held at the end of the presentations to address the questions received from in-person and virtual attendees. The discussion covered a wide range of topics such as inorganic analysis using high-accuracy measurement techniques, use of metrologically-traceable standard solutions and quality control materials, differences between accuracy- and consensus-based PT, organisation of APEC PT, etc.

On 8 March 2023 (Day 3), Workshop participants celebrated International Women's Day with a special panel discussion. Three accomplished women in Science, Technology, Engineering and Mathematics (STEM), Dr Angela Samuel from NMIA, Ms Anita Rani from NABL and Dr Shima Hashim from KIMIA presented on their roles in the wider scientific community as well as their views on the skills and attributes that have contributed to their achievements. The session concluded with an inspiring video-recording on Women in STEM from the CEO of SSC, Ms Chantal Guay.

Afterwards, the sessions focused on giving an overview of the production of RMs for laboratory use as well as group discussion on case studies relevant to this topic.

The theme of the last day of the Workshop was Establishing Sustainable Quality Infrastructure for Current and Future Testing Needs. The attendees were assigned into 4 groups to discuss the existing regulatory frameworks and standards and conformance networks in participants' economies, the developmental status of their institutes/organisations, testing parameters of concern, and their access to instrumentation, training, expertise and other resources. It was also aimed to gather information on the institutes'/laboratories' action plans, including new measurement capabilities and testing or metrological services, as well as their capacity and capability building needs. To better facilitate this group discussion, another pre-workshop survey (using FORMSG electronic form - See Annex J) was sent to in-person attendees. A total of 25 individuals from 23 economies responded to the survey, of whom 48.0% (12 out of 25) were from APEC economies. The questions covered in this survey were discussed by the groups and presented to the rest of the attendees.

With regards to the regulatory framework in participants' economies, the majority of the respondents (12 to 15 out of 25) stated that the framework could be further enhanced by including more (potentially) hazardous compounds, implementing more rigorous testing regimes and setting more stringent safety limits. A significant proportion of the respondents (14 to 17 out of 25) also noted that the standards and conformance network in their region could be further enhanced through provision of relevant training and forming a closer network between accreditation bodies and testing laboratories. See Figure 6a for the survey results.



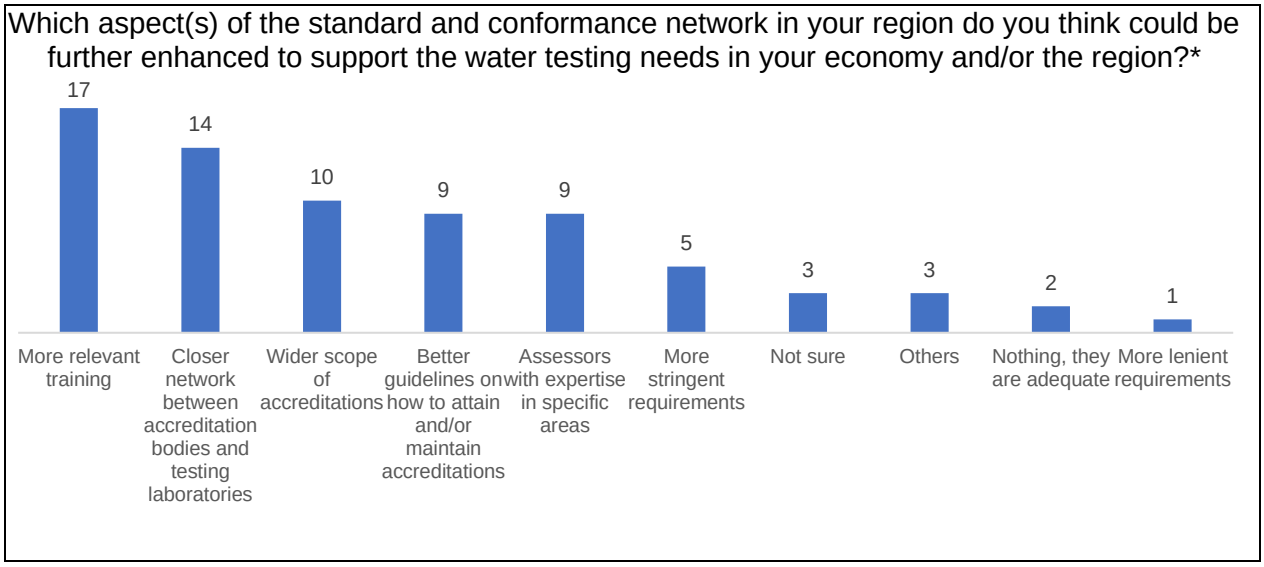


Figure 6a: Charts showing the pre-workshop survey questions (in-person) and responses from 25 individuals. *Denotes multiple selection was allowed.

The developmental status of the participants' institutes/organisations, including their human resources, services offered, access to metrological services, accreditation status with regards to water testing as well as their level of funding, was also captured through the survey.

With regard to the level of competency of technical staff pertaining to measurement of parameters relevant to water quality, 48.0% (12 out of 25) of the respondents shared that the technical staff were competent. Only 8.0% (2 out of 25) and 16.0% (4 out of 25) stated that the technical staff were somewhat competent and not competent in some areas, respectively. They noted that in-house training, workshops or seminars and training attachments could improve staff competency. The level of technical staff retention within the organisation was deemed to be high by 40.0% (10 out of 25) of the respondents. A small proportion of 12.0% (3 out of 25) and 24.0% (6 out of 25) stated that technical staff retention was low and medium, respectively. Higher salaries and/or benefits, better working environments, better career prospects and change of job scopes were leveraged to improve staff retention. See Figure 6b for the survey results.

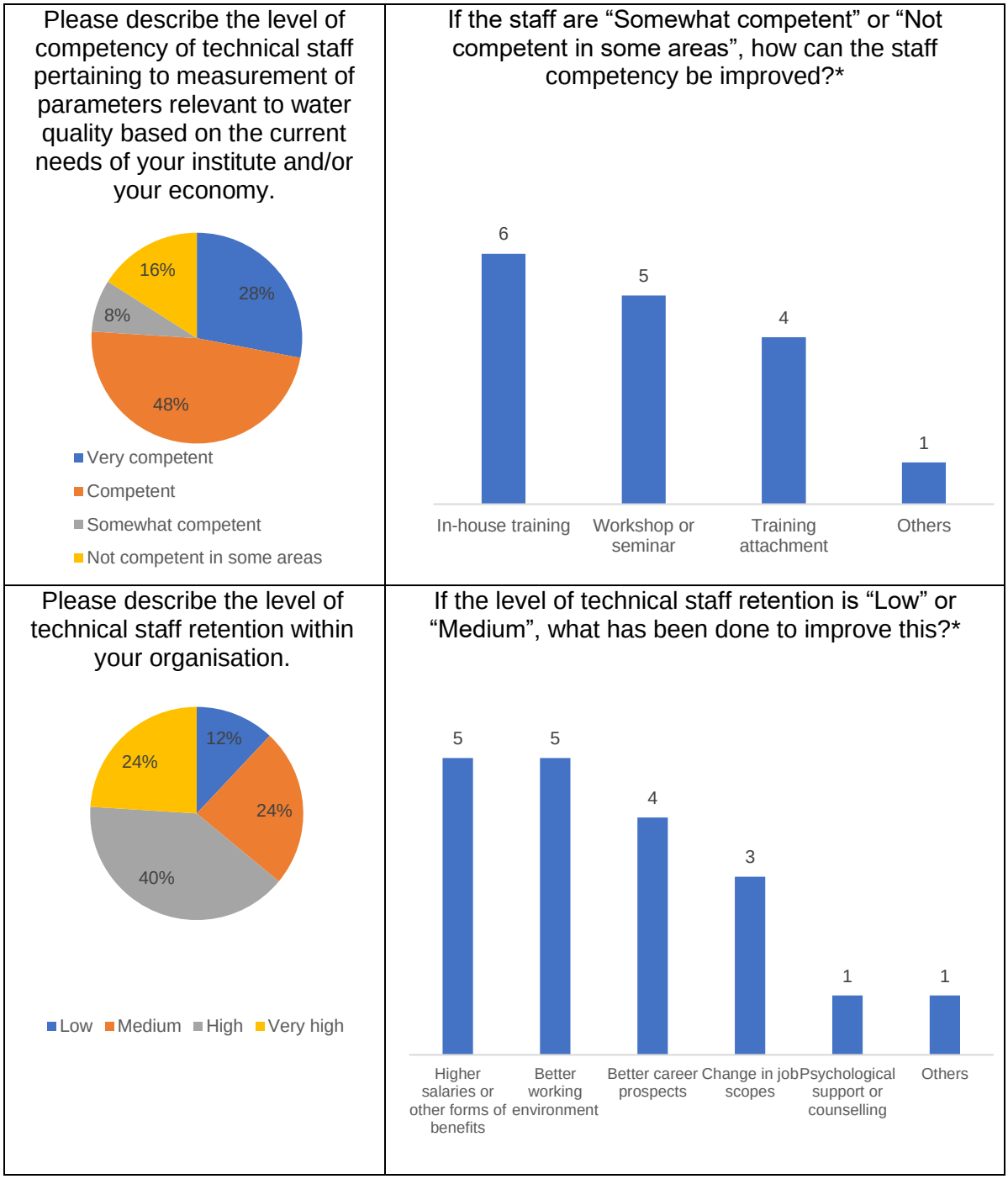
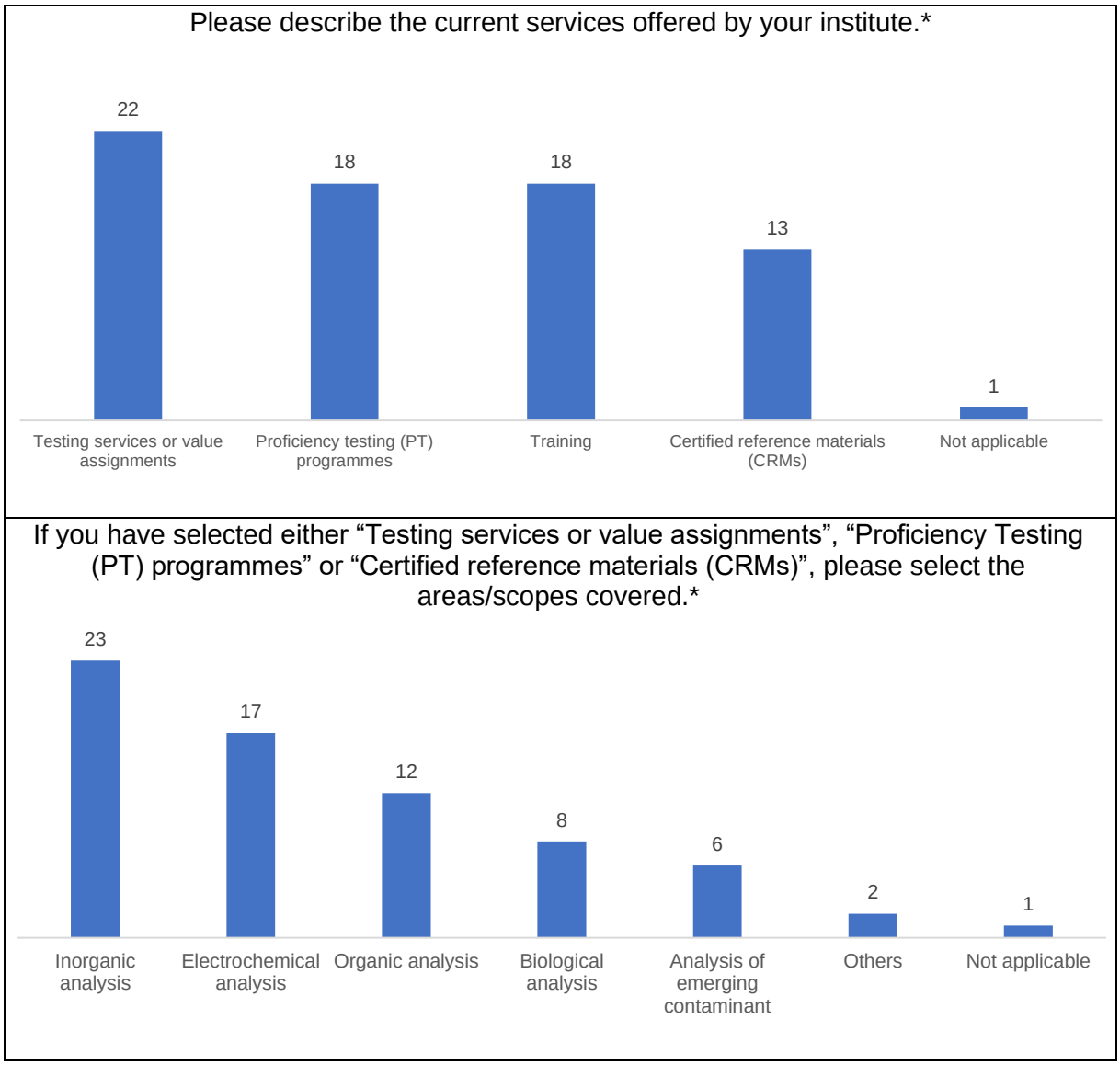


Figure 6b: (Continued) Charts showing the pre-workshop survey questions (in-person) and responses from 25 individuals. *Denotes multiple selection was allowed.

During the group discussion, multiple issues pertaining to staff competency were identified and discussed. Several groups pointed out that the levels of education provided by local universities in some economies were inadequate to support the needs of chemical testing laboratories and metrology institutes and that metrology was generally not covered in the current education system. As well, several emerging institutes/organisations face challenges with staff recruitment either due to political reasons, lack of funding or lack of interest in scientific fields. Personnel issues faced by developed institutes/organisations typically related to the imbalance between

technical personnel holding advanced degrees (Masters or PhD) and general university degrees or lower to carry out research vs. routine testing activities.

At least 88.0% (22 out of 25) of the respondents provide testing services or value assignments, while 72.0% (18 out of 25) provide PT and/or training and 52.0% (18 out of 25) are CRM providers. The scope of testing services or value assignments, PT and/or CRM mostly covered inorganic, electrochemical and organic analyses. The training provided by the respondents or their institutes/laboratories was mostly in measurement uncertainty, method validation, International Standards and technical areas. The two most prominent challenges that were highlighted by the respondents were insufficient funding support and lack of human resources. In addition to these two challenges, limited access to instrumentation and inadequate facilities, limited networks with other stakeholders and limited measurement capabilities and access to training were also identified as obstacles in service deliveries. See Figure 6c for the survey results.



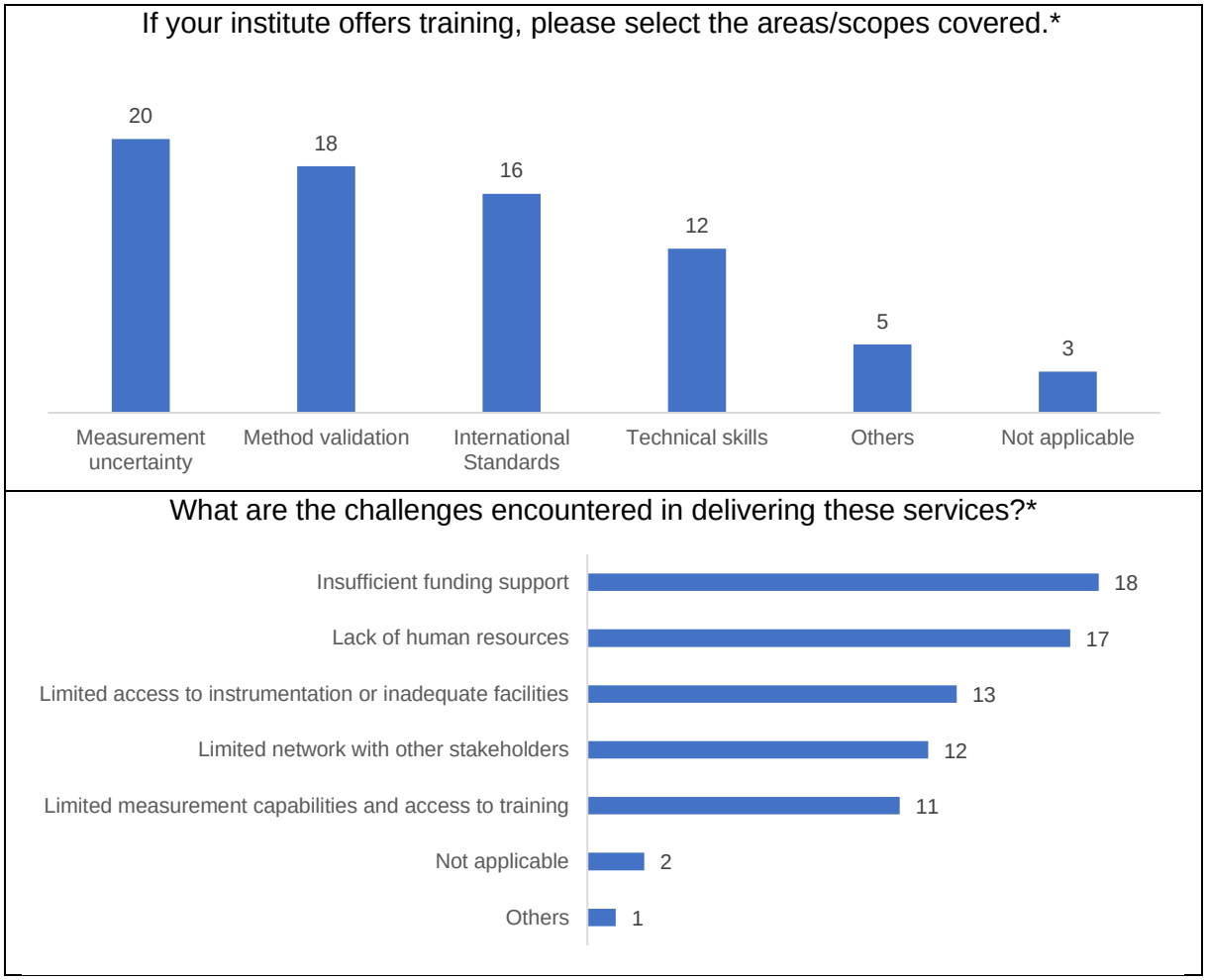


Figure 6c: (Continued) Charts showing the pre-workshop survey questions (in-person) and responses from 25 individuals. *Denotes multiple selection was allowed.

Only 8.0% (2 out of 25) of the respondents identified that current needs or demands for metrology services in their economies were fulfilled, while 44.0% (11 out of 25) and 48.0% (12 out of 25) stated that they were somewhat fulfilled or not fulfilled in some areas, respectively. A few approaches could be taken to help fulfil the needs or demands for metrology services, including offering wide scopes of services, increasing the frequencies (e.g., for PT), bringing in more experts, increasing the volume or capacity as well as improving service quality. See Figure 6d for the survey results. During the group discussion, the need and intent to offer wider scopes of services were also mentioned frequently by several attendees.

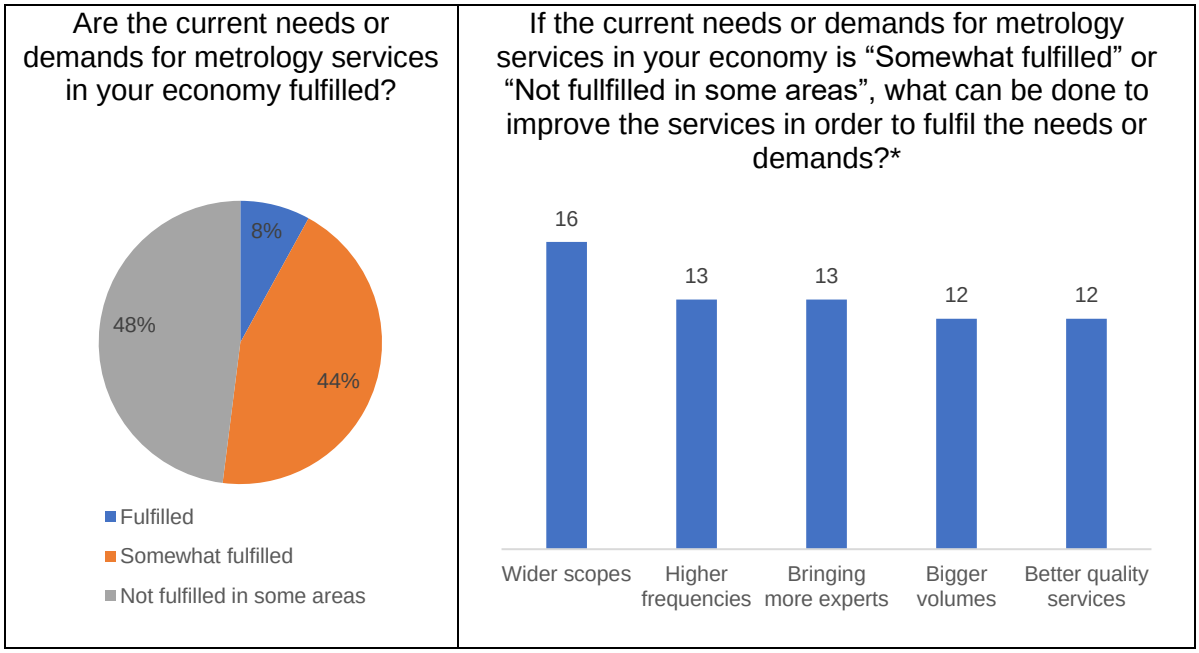
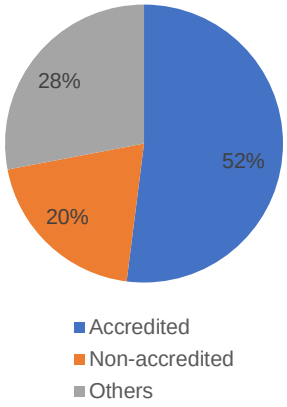


Figure 6d: (Continued) Charts showing the pre-workshop survey questions (in-person) and responses from 25 individuals. *Denotes multiple selection was allowed.

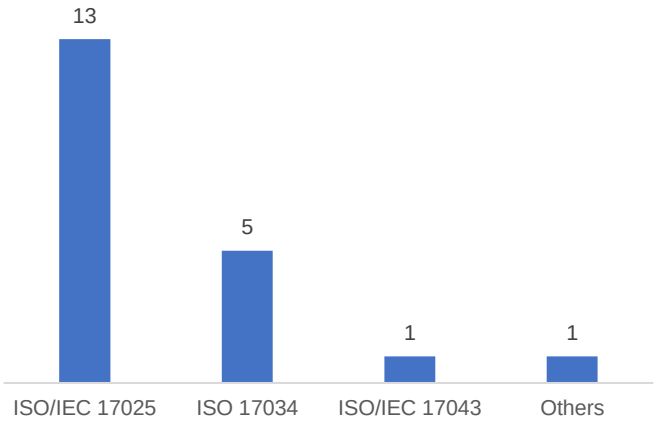
Based on the survey, 63.2% (36 out of 57) of the respondents are accredited for water testing and 26.3% (15 out of 57) are not, though they are providing services in the area. Another 10.5% (6 out of 57) are not providing water testing services. The top three accreditation scopes for water testing covered inorganic parameters, electrochemical parameters and nutrients. These were consistent with the scopes that the respondents wished to be covered in the next regional water PT programme. The majority, or 73.7% (42 out of 57) of the respondents shared that they plan to seek accreditation or extend their accreditation scopes to cover more areas of water testing. Inorganic parameters were identified as the top parameters in which respondents intend to apply or extend their accreditation scopes.

Consistent with the outcome of the pre-workshop survey for all participants, the majority of respondents, 52.0% (13 out of 25) came from accredited water testing laboratories while 20.0% (5 out of 25) are not, though they are providing services in the area. Another 28.0% (7 out of 25) of the respondents are not providing water testing services. Most of the respondents were from ISO/IEC 17025 accredited laboratories. Some were also accredited CRM producers (ISO 17034 accredited) and PT providers (ISO/IEC 17043 accredited). However, it is important to highlight that the number of institutes that are currently accredited for ISO 17034 and ISO/IEC 17043 is much lower than the number of institutes that provide CRMs and PT (see Figure 6c). This indicates that several CRM and PT providers are still at the stage of seeking accreditation. The top three accreditation scopes for water testing covered inorganic, electrochemical and biological analyses. The majority, or 88.0% (22 out of 25) of the respondents shared that they plan to seek new accreditation or expand their accreditation scopes to cover more areas of water testing or both. Inorganic parameters were identified as the top parameters in which respondents intend to apply or extend their accreditation scopes. See Figure 6e for the survey results.

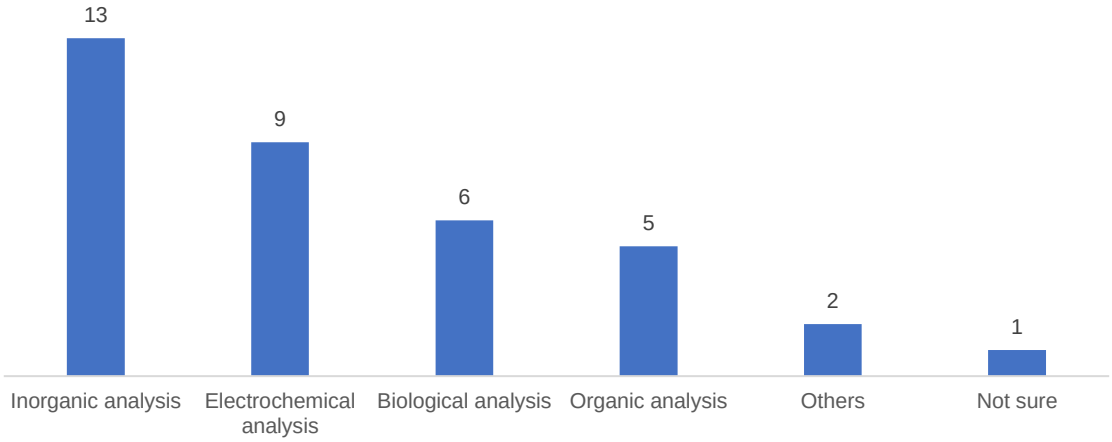
Please describe the accreditation status in respect of water measurement of your institute.



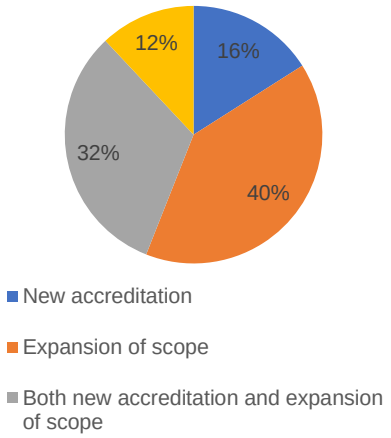
Please select which Standard your institute is accredited for in respect of water measurement.*



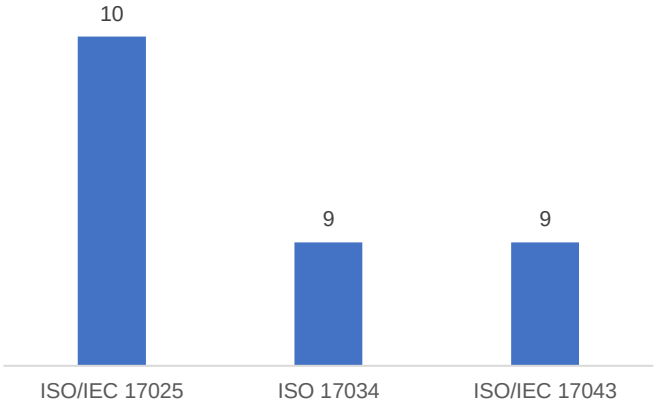
Please select your institute's current scope of accreditation.*



Is your institute intending to go for a new accreditation or to expand the scope of your accreditation in the next 5 years?



Please select which Standard your institute plans to be accredited for in respect of water measurement.*



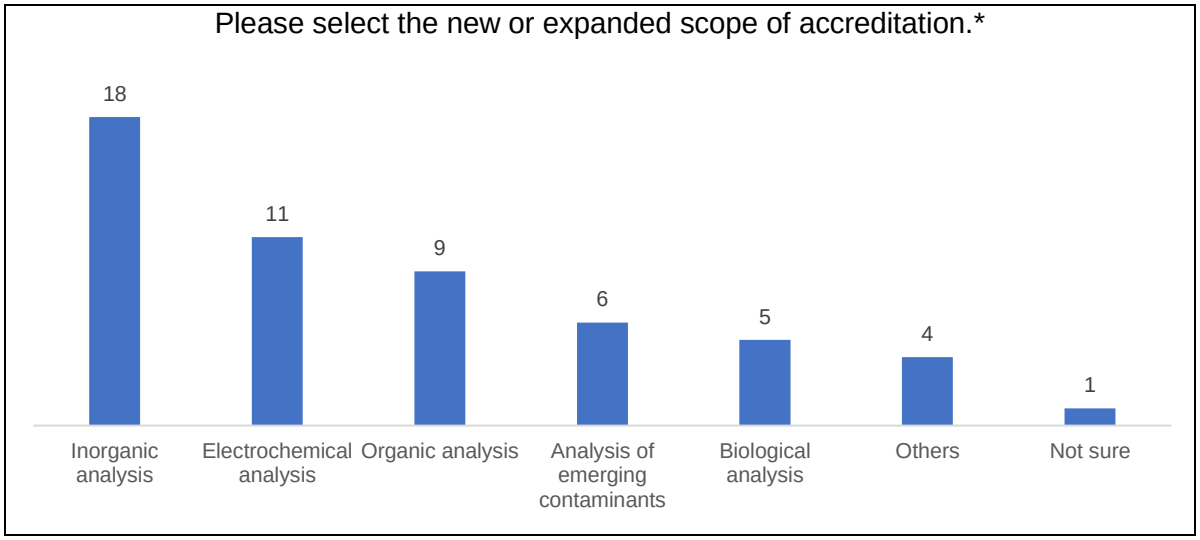


Figure 6e: (Continued) Charts showing the pre-workshop survey questions (in-person) and responses from 25 individuals. *Denotes multiple selection was allowed.

Only 4.0% (1 out of 25) of the respondents stated that funding levels of their institute were more than sufficient, while 8.0% (2 out of 25) and 24.0% (6 out of 25) of the respondents stated that they were generally sufficient or almost sufficient, respectively. A large percentage of the respondents, 48.0% (12 out of 25), stated that funding levels were insufficient. Some respondents preferred not to disclose. See Figure 6f for the survey results.

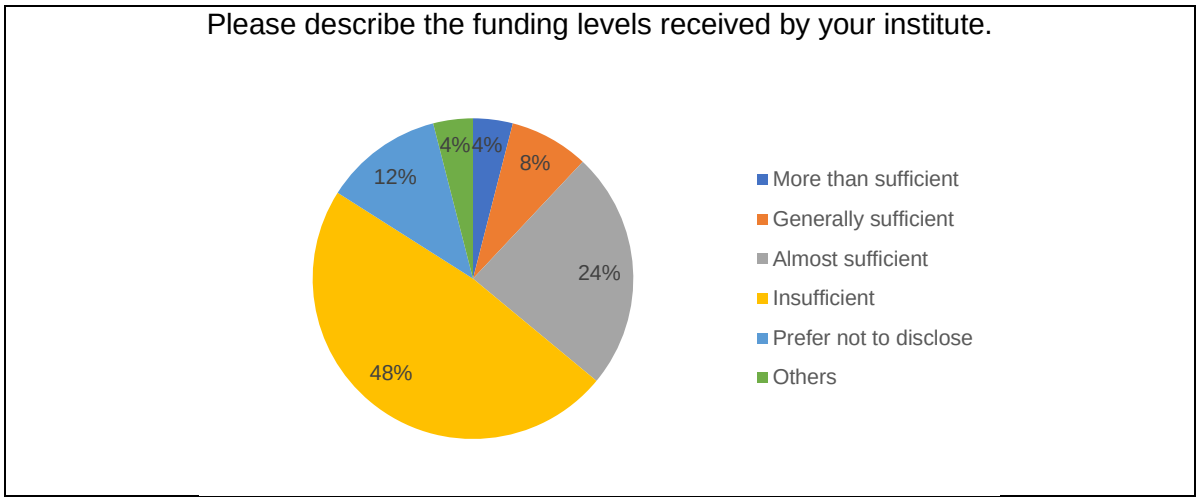
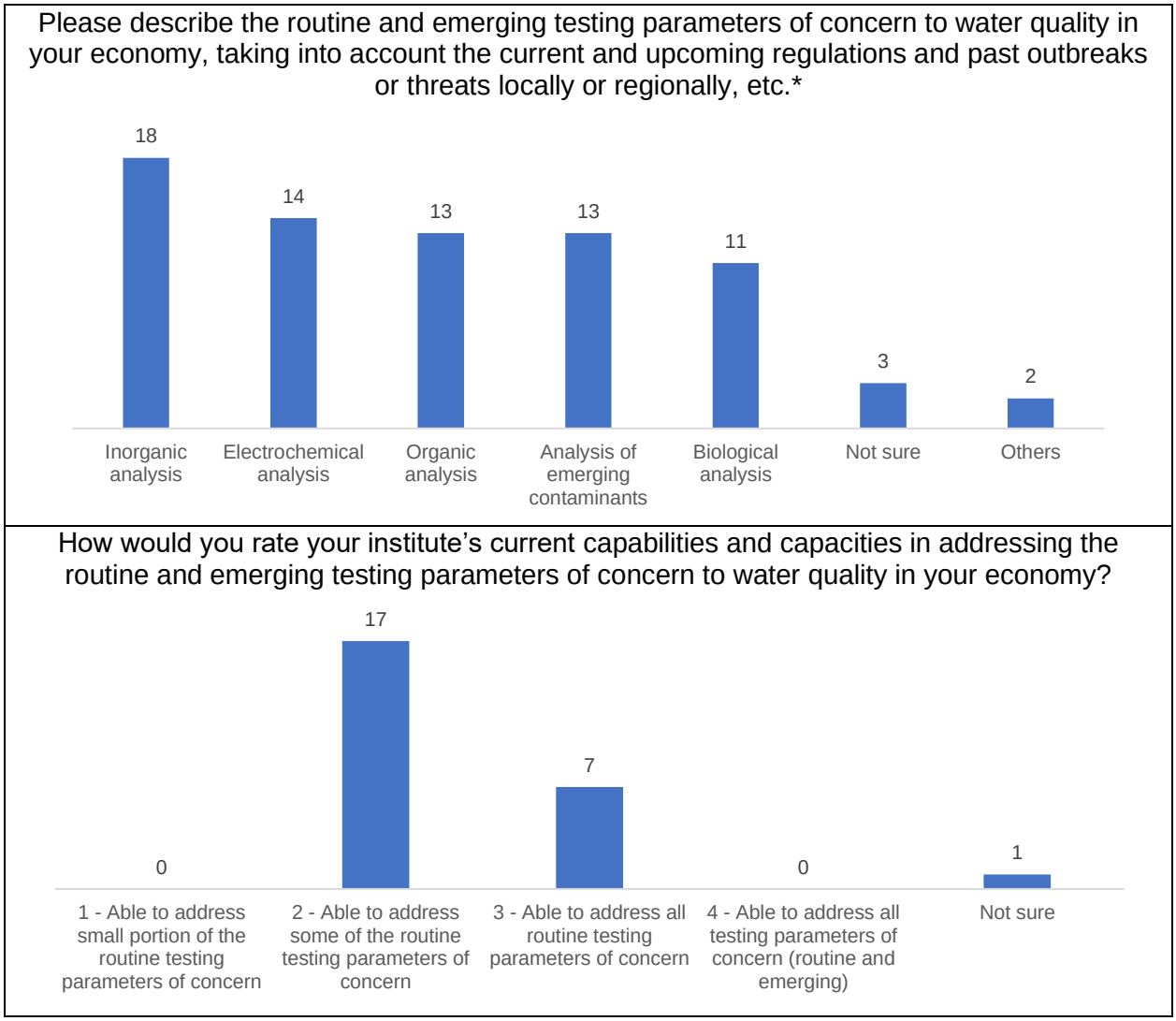


Figure 6f: (Continued) Charts showing the pre-workshop survey questions (in-person) and responses from 25 individuals.

Funding levels and sources were also discussed extensively at the Workshop. Some of the attendees mentioned that most of the funding comes from their governments or ministries, collaborative projects with other institutes/organisations, and income generated from testing or metrological services. However, income generated from metrological services was usually insufficient. Generally, more funding is required to purchase more advanced instrumentation, perform maintenance, purchase consumables and receive hands-on application training.

The routine and emerging testing parameters of concern to water quality identified by the respondents included inorganic, electrochemical and organic analysis as well as

analysis of emerging contaminants and biological parameters. About 68.0% (17 out of 25) of the respondents noted that their institutes' current capabilities and capacities were sufficient to address some of the routine testing parameters, while 28.0% (7 out of 25) responded that their institutes' current capabilities and capacities were sufficient to address all routine testing parameters. No respondent indicated that their institute was able to address all testing parameters of concern, including emerging parameters. For respondents who stated that their institutes' current capabilities and capacities were sufficient to address only some of these testing parameters, a few approaches could be taken to address this gap, primarily through training attachments as well as workshops and seminars. See Figure 6g for the survey results.



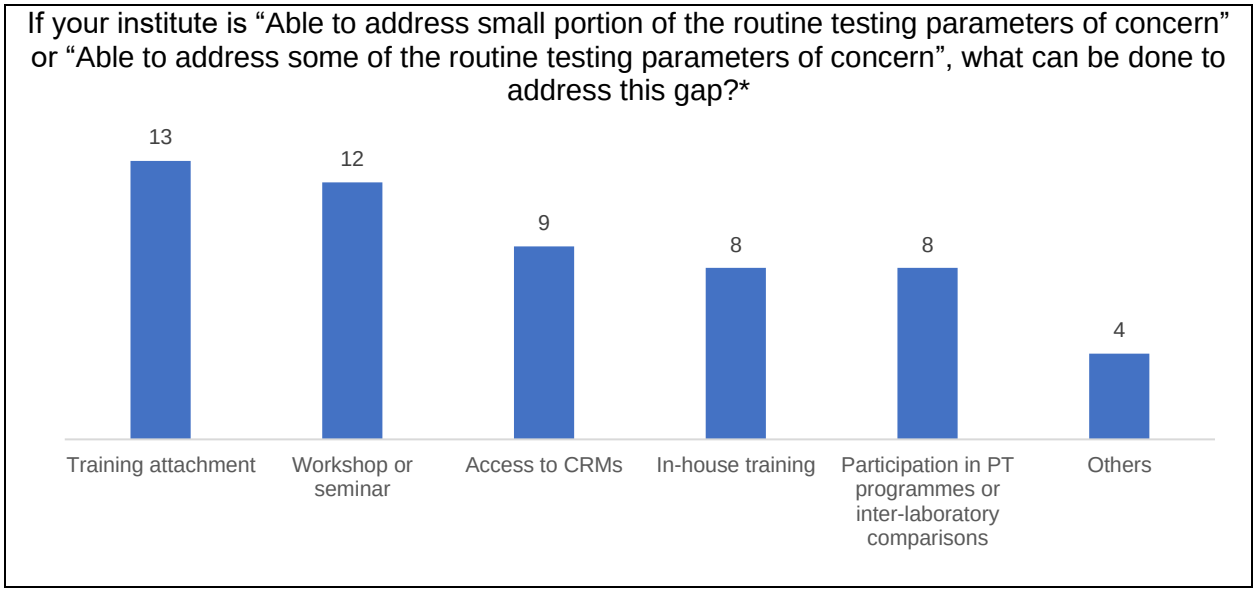
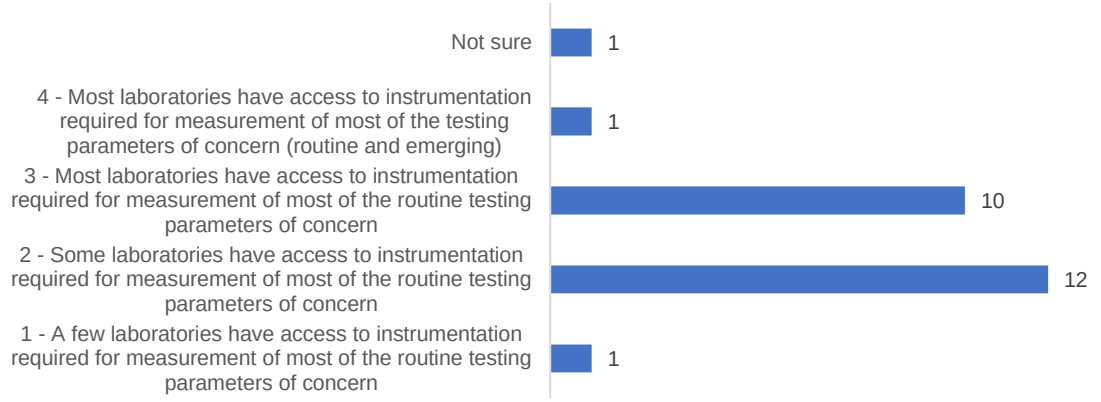


Figure 6g: (Continued) Charts showing the pre-workshop survey questions (in-person) and responses from 25 individuals. *Denotes multiple selection was allowed.

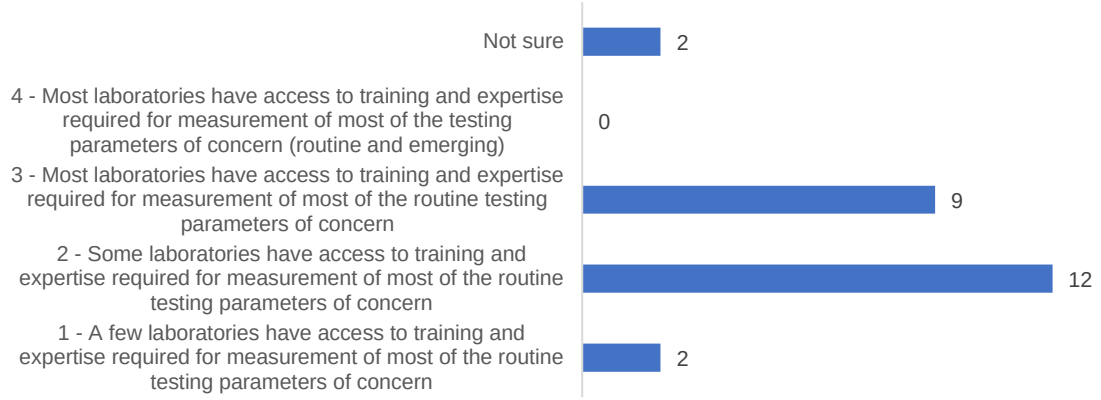
The group discussion provided the opportunity for attendees to elaborate on the specific analytes of concern to water quality in their economies. Inorganic, electrochemical and organic analysis as well as analysis of emerging contaminants and biological parameters had been identified through the survey. For inorganic analysis, heavy metals and anions were of concern. For electrochemical analysis, the specific parameters included pH, conductivity, turbidity, hardness and colour. For organic analysis, pesticides, aflatoxins and several biotoxins had been highlighted. Micro- and nano-plastics as well as nanoparticles were considered as important emerging testing parameters for water quality.

The respondents were also asked to rate access that the water testing laboratories in their economies have to instrumentation as well as training and expertise required for the measurement of the testing parameters of concern to water quality in their economy. Regarding access to instrumentation, about 48.0% (12 out of 25) of respondents stated that some laboratories have access to instrumentation required for measurement of most of the routine testing parameters of concern, while 40.0% (10 out of 25) responded that most laboratories have access to required instrumentation. Similarly, about 48.0% (12 out of 25) of respondents noted that some laboratories have access to training and expertise required for measurement of most of the routine testing parameters of concern, while 36.0% (9 out of 25) stated that most laboratories have access to training and expertise required for these measurements. Networking with other laboratories within the economy or region was recognised as one of the important requirements for the measurement of the testing parameters of concern to water quality in their economies, along with access to PTs and chemicals as well as adequate laboratory setups. See Figure 6h for the survey results.

How would you rate the access that the water testing laboratories in your economy have to instrumentation required for the measurement of the testing parameters of concern to water quality in your economy?



How would you rate the access that the water testing laboratories in your economy have to training and expertise required for the measurement of the testing parameters of concern to water quality in your economy?



Is there any other resource(s) required for the measurement of the testing parameters of concern to water quality in your economy?*

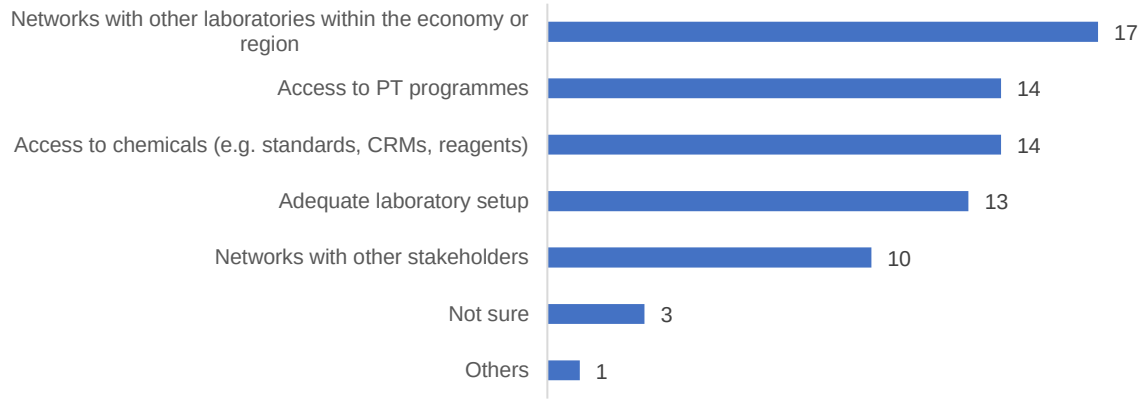
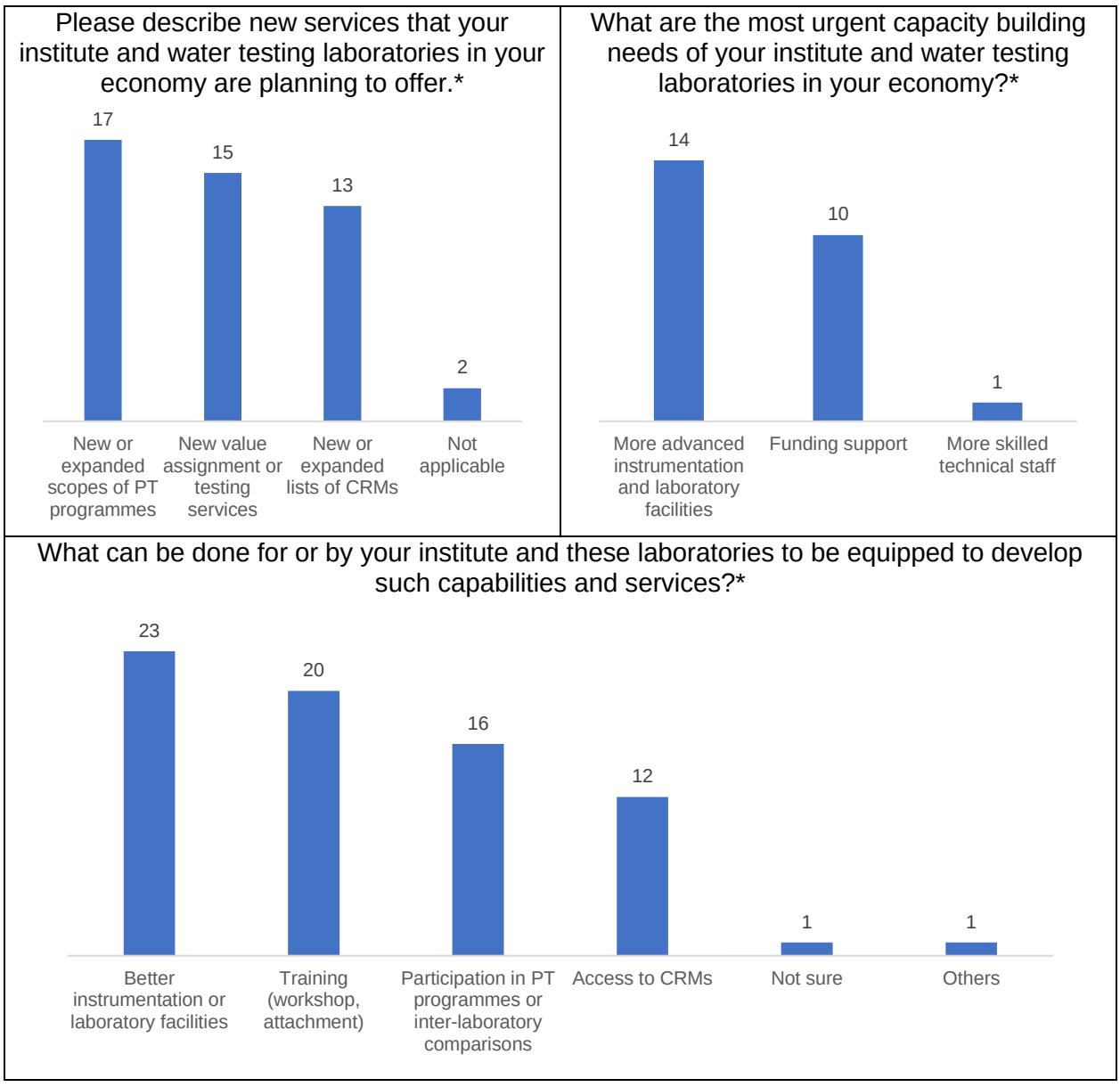


Figure 6h: (Continued) Charts showing the pre-workshop survey questions (in-person) and responses from 25 individuals. *Denotes multiple selection was allowed.

The respondents were also asked about new services that their institutes and water testing laboratories in their economies were planning to offer. More than half of the respondents stated that there were plans for either new or expanded scopes of PT

programmes, value assignment or testing services and/or CRMs. The most urgent capacity building needs that were recognised through the survey were for more advanced instrumentation and laboratory facilities as well as funding support. Other than better instrumentation and laboratory facilities, training, participation in PT programmes or inter-laboratory comparisons and access to CRMs were considered critical by respondents in ensuring that the laboratories are equipped to develop new services. The respondents specified that capability building activities that cover technical skills (e.g., isotope dilution mass spectrometry, standard addition) would be most relevant to their institutes and economies. As well, testing and/or calibration requirements (in accordance with ISO/IEC 17025) were deemed to be highly relevant for their economies. See Figure 6i for the survey results.



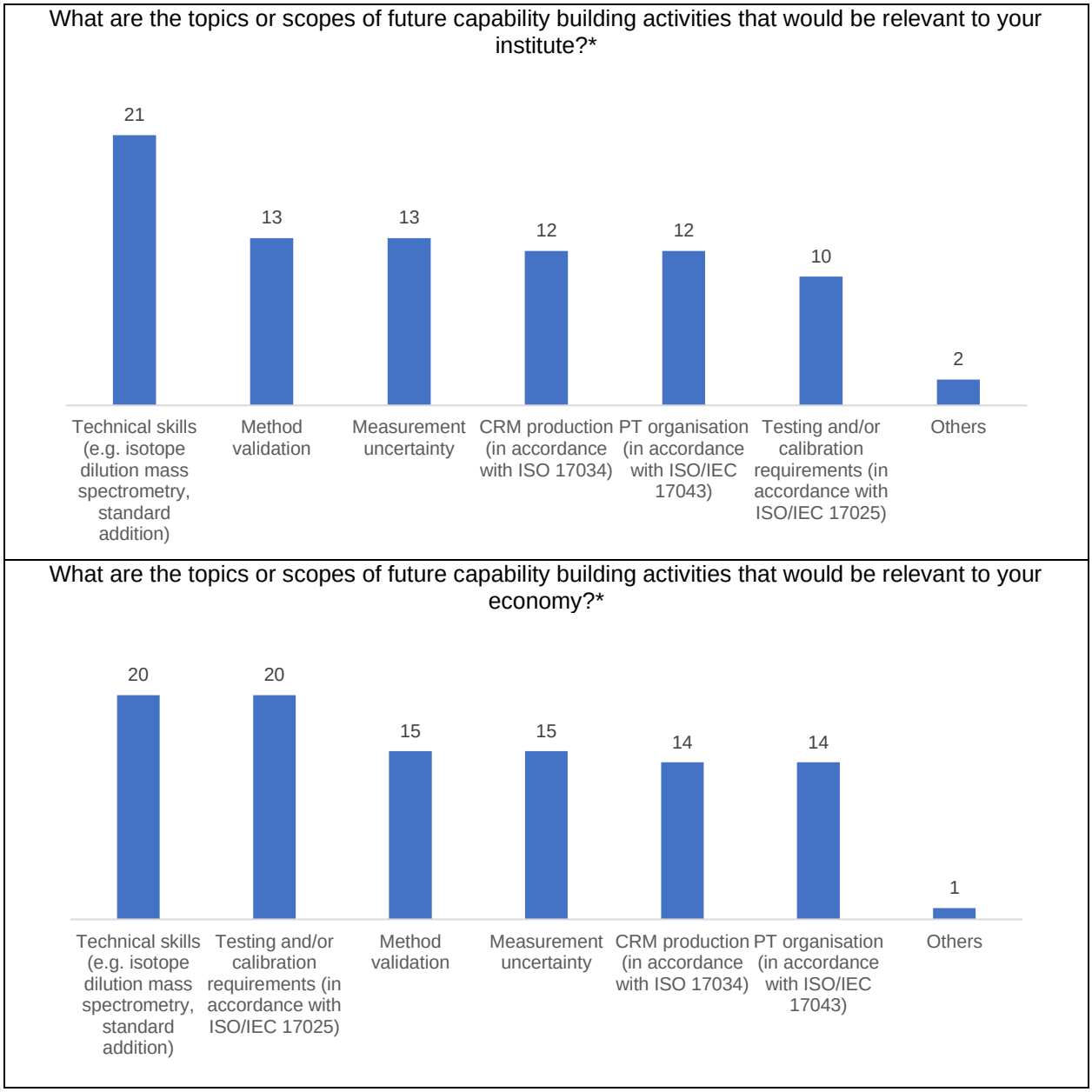


Figure 6i: (Continued) Charts showing the pre-workshop survey questions (in-person) and responses from 25 individuals. *Denotes multiple selection was allowed.

Attendees funded by APMP DEC & SIM, that did not participate in the APEC Water PT or APMP.QM-P41 and SIM.QM-S12 were also given the opportunity to present updates on the chemical metrology programmes in their institutes that were relevant to water quality. Generally, these institutes' developmental stages were fairly scattered. Some institutes were considered mature, as they participated in several regional and international comparisons, had multiple CMCs in the measurement area and provided metrological services, such as PT and CRMs. However, some institutes were still setting up their chemical metrology laboratories or building their metrological capabilities through participation in relevant pilot studies. The general challenges shared by these institutes include limited funding, lack of human resources and access to training, as well as public awareness of the importance of chemical metrology.

Photographs taken during the Post-Measurement Workshop were shown in Annex K.

6.4 LEVEL OF PARTICIPATION OF WOMEN AND KEY OUTCOMES OF SURVEY FOR WOMEN IN STEM

Table 6 details the breakdown of Post-Measurement Workshop attendees based on gender. Considering both APEC and non-APEC economies, 58.3% and 56.8% of in-person and online attendees were women.

Table 6: Breakdown of Post-Measurement Workshop attendees based on gender.

	Onsite	**Online**	**Total**
Female	21	25	46
Male	15	19	34
Total	36	44	80
%Female	**58.3%**	**56.8%**	

The Organising Committee was chaired by a female and comprised equal representation of female and male experts from metrology institutes and accreditation bodies, all of which are based in APEC member economies. The Workshop was launched by a female Project Overseer. The first talk of the workshop was presented by a female expert from a water regulatory body. Hence, the Workshop had achieved an excellent gender balance in respect of project design and implementation.

Following the celebration of International Women's Day with a special panel discussion, a survey (using FORMSG electronic form - See Annex L) was launched to gather information from the attendees on the level of female representation in their laboratory as well as female involvement in the APEC Water PT. Their opinions on opportunities and challenges faced by women in STEM as well as insights on their institutes' policy to ensure equal opportunities for women were sought. The detailed outcomes can be found in Annex L.

One of the key outcomes to be highlighted from this survey includes 59.3% of the respondents indicated that they did not observe or experience any barrier for women to gain equal opportunities to advance their careers in STEM. Majority of the respondents (66.7%) also stated that their institutes/laboratories did not have any policy / programme to ensure equal opportunities for women The key success factors that inspired participants the most from the panel session are shown in Figure 7.

Figure 7: Charts showing the women in STEM survey questions and responses from 27 individuals. Key success factors that inspired participants the most from the panel session.

6.5 KEY OUTCOMES OF POST-WORKSHOP SURVEY

After the completion of the Post-Measurement Workshop, the Organisers sought feedback from the attendees through a post-workshop survey (using FORMSG electronic form – See Annex M). There were 60 respondents, i.e., about 75% of the attendees of the workshop provided feedback. The detailed outcomes of the post-workshop survey can be found in Annex M.

In summary, all respondents found the Workshop topics to be mostly or very relevant to themselves or their economies (average score of 4.7 out of 5.0). All respondents either strongly agree or agree that the topics were relevant to their work (average score of 2.8 out of 3.0). The average score of the level of knowledge/technical know-how were 4.0 and 4.5 out of 5.0 before and after the Workshop, respectively. Between 96.7% and 100.0% of the attendees agreed or strongly agreed that the objectives of the workshop were clearly defined and achieved; the content was well organised and easy to follow; gender issues were sufficiently addressed; the speakers had provided sufficient materials and they were well prepared and knowledgeable; the workshop was well-paced; and the selected platform was user-friendly and allowed interactions with the speakers. The average scores for these indicators were between 2.7 to 2.9 out of 3.0.

7. KEY TAKEAWAYS

The project objective and scope were clearly defined at the beginning of the project to build laboratories capabilities to measure water quality in Asia-Pacific economies through workshops and PT. The clear scope and objective helped to ensure that the resources could be allocated well, and the project could be completed within the given timeline.

Regularly engaging with stakeholders throughout the project, including counterpart metrology institutes and accreditation bodies, as well as regulatory bodies and testing laboratories, and obtaining their feedback was essential to ensure that the project met their needs and expectations.

8. RECOMMENDATIONS

There are several recommendations that the Project Overseer Team would like to make in order to build on the efforts in this project to develop laboratories capabilities to measure water quality in Asia-Pacific.

a. Develop a capacity building programme to train scientists and technicians on the use of advanced measurement equipment and techniques. This could include training programmes, workshops, and training attachments to provide hands-on experience.
b. Encourage technology transfer from developed economies that have advanced measurement capabilities to those with emerging and developing capabilities. This could involve partnerships with metrology institutes, testing laboratories, research institutions, or even private companies that can provide access to the latest equipment and techniques.
c. Encourage knowledge transfer within an economy which had received training from other developed economies with more advanced capabilities through the use of “train the trainer” approach that we have adopted in the project.
d. Establish regional communities focusing on water quality measurements to enable information sharing across different economies, such as APMP CWFG. This would provide a better understanding of water quality trends and facilitate the development of effective policies and regulations.
e. Increase public awareness about the importance of water quality and the need for accurate measurements. This could involve public education campaigns, workshops, and other outreach programmes to inform the public about the risks of contaminated water, benefits of clean water and the responsibilities of the public in protecting the water resources.

It is anticipated that by implementing these recommendations, Asia-Pacific economies with capability gaps could further strengthen their water quality measurement capabilities, improve their understanding of water quality trends, and take steps to address water quality issues to protect public health and the environment.

9. CONCLUSION

Through the workshops and PT, this project has helped the laboratories in building their capabilities and achieving comparability through internationally recognised measurement, quality and accreditation frameworks. The project successfully involved experts from the science, international metrology community (APMP and SIM), standard and conformance network (APAC), and regulatory bodies [Public Utilities Board (PUB), Health Canada], as well as World Health Organisation Collaborating Centres and attracted participation from many testing laboratories and metrology institutes both within and outside the APEC region.

Through the project, the experts has shared knowledge of the regulatory frameworks; strengthened participants’ understanding of core measurement concepts: analytical measurement techniques, metrological traceability, conformity, and uncertainty of measurement testing and sampling; helped the participants appreciate the importance

of accuracy-based PT and CRMs; provided opportunities for participants to apply the knowledge gained and to evaluate and enhance their measurement capabilities in determining elements in a water matrix; provided an avenue for participants to share their experiences in undertaking the measurements, to identify further needs and to develop action plans for future strategies to improve laboratory practices and measurement capabilities.

Overall, this project has provided a sound foundation from which economies could further build their capabilities as needed to address emerging priorities and ensure ongoing relevance and sustainability of their water quality measurement and testing capabilities.

Table 7 summarises the measurable outcomes as indicated in the Project Proposal that have been detailed in various section (indicated in blue) of this report.

Table 7: Measurable outcomes of the project.

	Impacts	**Expected changes and benefits**	**Key Indicators**
1	Behaviour changes in staff from participating institutes and laboratories from developing economies	Greater commitment to improving measurement capabilities and systems Improved technical competence	• Participation rate in Preparatory Workshop: *See Section 4.3.* • Participants' feedback from Preparatory Workshop evaluation reports: *See Section 4.4.* • Participation rate in the PT: *See Section 5.2.* • Participation rate in Post-measurement Workshop: *See Section 6.3.* • Participants' feedback from Post-measurement Workshop evaluation reports: *See Section 6.5.*
2	Extension and/or maintenance of scope of accredited services of participating institutes and laboratories	Ability for participating institutes and laboratories to provide reliable and internationally recognized measurement and testing capabilities	Preparation to extend/maintain scope of accredited services: *See Section 6.2.*
3	Credible scientific basis for evaluation of capabilities of participating institutes and laboratories and for development of next-stage capacity building measures.	Ongoing demonstration by measurement institutes of commitment to improving their measurement capabilities Ongoing commitment of testing laboratories to improving their technical competence	The PT report provides participating institutes and laboratories with the means of benchmarking their performance with reference values from established metrology institutes as well as identifying gaps for future action (e.g. follow-up PTs): *See Sections 5 and 6.*

As part of the Project Overseer Team's commitment to ensure adherence to APEC's Monitoring and Evaluation system and reporting requirements through the following targets in Table 8, the outcomes are provided in blue.

Table 8: Targets and outcomes based on APEC's Monitoring and Evaluation system and reporting requirements.

	Outcome	**Key Indicators**	**Targets**	**Outcome**
1	Project effectiveness measured through participation	Participation rate in Preparatory Workshop Participation rate in PT	a) Preparatory Workshop: 10 – 15 institutes b) ~100 laboratories in PT c) Post-measurement Workshop: ~ 10 institutes	a) Exceeded b) 64 Laboratories registered for PT and 54 submitted results*

	Outcome	Key Indicators	Targets	Outcome
		Participation rate in Post-measurement Workshop Experts engaged for both Workshops Participants' feedback based on Workshop evaluation reports	d) ~10 experts for both workshops	c) Exceeded d) Exceeded
2	Project effectiveness measured through readiness of participating institutes and laboratories to apply for extension of scope of accredited services	Preparation by participating institutes and laboratories to support accredited scope and/or extend scope of accredited services	More than 50% of participating institutes/laboratories use their PT results to demonstrate compliance with the Quality Assurance Requirement (clause 7.7.2) of ISO/IEC 17025 in applying for assessment of new testing scope and/or reassessment of existing testing scope	59% of the participating institutes/laboratories are using accredited methods to demonstrate their capability and can potentially use the PT to demonstrate their continued competence.

**a) 18 Institutes registered for the parallel-run SIM Supplementary Comparison and/or APMP pilot study.*
b) Including the APEC Water PT and parallel-run SIM Supplementary Comparison and/or APMP pilot study, 90% participation was from 21 APEC member economies.
c) Owing to the tightness of the schedule, the PT Coordinators only offered a quota of 2 water testing laboratories per Accreditation Body (AB) at the invitation stage. A few ABs indicated their wishes to nominate more than 2 laboratories. If more time was available for the call for participants and making fine adjustments, it was expected that the target of ~100 laboratories could be achieved.

Table 9 shows the budget summary report for this project. Only 23.0 % of the approved budget were utilised.

Table 9: Budget summary report.

Item Description	Approved Budget	Current Budget	Paid	Balance
GENERAL				
Event Cost				
Hosting	11,016.00	11,016.00	2,545.57	8,470.43
Travel by Participants				
Airfare	55,000.00	55,000.00	8,823.34	46,176.66
Per Diem	53,383.00	53,383.00	10,622.00	42,761.00
Travel by Speakers, Experts, Researchers				
Airfare	35,000.00	35,000.00	11,952.26	23,047.74
Per Diem	12,133.00	12,133.00	4,324.00	7,809.00
Total GENERAL :	**166,532.00**	**166,532.00**	**38,267.17**	**128,264.83**
	166,532.00	**166,532.00**	**38,267.17**	**128,264.83**

REFERENCES

[1] https://www.apec.org/Meeting-Papers/Sectoral-Ministerial-Meetings/Food-Security/2021_food_security/Annex

[2] https://www.un.org/sustainabledevelopment/water-and-sanitation

[3] https://www.unwater.org/publications/un-world-water-development-report-2021

[4] https://ec.europa.eu/environment/water/water-framework/info/intro_en.htm

[5] ISO/IEC 17043:2010 Conformity Assessment – General Requirements for Proficiency Testing.

[6] ISO 13528:2015 Statistical Methods for Use in Proficiency Testing by Interlaboratory Comparison.

[7] BIPM key Comparison Database (https://www.bipm.org/kcdb/)

[8] W. Horwitz, Anal. Chem. 1982, 54, 67A-76A “Evaluation of analytical methods used for regulations of food and drugs”.

[9] ISO 17025:2017 “General requirements for the competence of testing and calibration laboratories”, 2017, Geneva, Switzerland.

[10] Information from the website of Royal Society of Chemistry: http://www.rsc.org/Membership/Networking/InterestGroups/Analytical/AMC/Software/kerneldensities.asp

ANNEX A

PROGRAMME BOOKLET FOR ONLINE PRE-MEASUREMENT WORKSHOP

Making an Impact on Water Quality for Public Health and Safety

Workshop on Building Laboratory Measurement Techniques

23 & 24 MARCH 2022 | 1:30-4:00 UTC | ZOOM WEBINAR

Supported by:

Asia-Pacific Economic Cooperation

INTRODUCTION

This virtual workshop aims to bring together experts from national water agencies, metrology institutes from the Asia Pacific Metrology Programme (APMP) and Inter-American Metrology System (SIM), as well as the Asia Pacific Accreditation Cooperation (APAC) to discuss key metrics of water quality data. The main objectives of the workshop are to strengthen participants' understanding of regulatory frameworks in some APEC economies, core measurement concepts, including analytical measurement techniques, metrological traceability, conformity, and uncertainty of measurement testing and sampling, and to help them appreciate the importance of accuracy-based proficiency testing. The presentations from technical experts in the area of inorganic analysis will also help the participants deal with potential challenges in the measurement of trace elements in water, and improve their measurement capabilities ahead of their participation in the international comparisons or proficiency tests.

DAY 1

23 March 2022, 1:30 - 4:00 UTC

The first session aims to provide an overview of the regulatory frameworks on water quality in some APEC economies and the standard methods applied by national water agencies for water monitoring. It also emphasizes the importance of CRMs and their availability from metrology institutes in the Asia Pacific and American regions. The value of accuracy-based proficiency tests as compared to consensus based ones will also be highlighted. This session would benefit Managers, Technical/Quality Managers and personnel in technical supervisory roles.

DAY 2

24 March 2022, 1:30 - 4:00 UTC

The second session aims to discuss core measurement concepts, including analytical measurement techniques, uncertainty of measurement testing and sampling. The presentations from technical experts in the area of inorganic analysis will also help the participants deal with potential challenges in the measurement of trace elements in water, and improve their measurement capabilities ahead of their participation in the SIM supplementary comparison (SIM.QM-S12), parallel APMP pilot study (APMP.QM-P41) or proficiency tests. This session would benefit Technical Managers, Scientists and Technical Professionals.

Please do not share the links to this online workshop provided to you. The workshop should only be accessed by confirmed registrants.

PROGRAMME

Note the local time of some economies in various time zones:
Santiago (Chile): 22 March 2022, 10:30 PM - 23 March 2022, 1:00 AM
Ottawa (Canada): 22 March 2022, 9:30 PM - 23 March 2022, 12:00 AM
Beijing (China): 23 March 2022, 9:30 AM - 12:00 PM
Sydney (Australia): 23 March 2022, 12:30 PM - 3:00 PM

DAY 1

23 March 2022, 1:30 - 4:00 UTC
Chair: Professor Zoltan Mester

WELCOME ADDRESS

Dr Angela Samuel

Project Overseer for APEC Project SCSC-01 2021 / Director, International Relations, National Measurement Institute, Australia (NMIA)

Dr Samuel is Director, International Relations, at NMIA. Dr Samuel has a PhD in Astronomy and Astrophysics from the Australian National University. Over more than 25 years, she has been driving, fostering and supporting NMIA's international relationships as well as international cooperation in metrology (measurement science). In particular Dr Samuel is very active in representing NMIA and Australia in the Asia Pacific Metrology Programme (APMP), and is currently chair of APMP's Developing Economies Committee. She has also had long-standing involvement in APMP's participation in the Sub-Committee on Standards and Conformance (SCSC) of the Asia Pacific Economic Cooperation (APEC).

PLANS FOR THE APEC PROJECT

Professor Zoltan Mester

Team Leader, Inorganic Chemical Metrology, National Research Council (NRC) of Canada

Professor Mester has been with NRC since 1999. He is an Adjunct Professor with the Queen's University, Chair of the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM)'s Isotope Ratio Analysis Working Group and Chair of the Canadian Mirror Committee for ISO TC 334. To date, he has published close to 300 articles.

PROGRAMME

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DAY 1

23 March 2022, 1:30 - 4:00 UTC
Chair: Professor Zoltan Mester

WATER QUALITY MONITORING BASED ON SINGAPORE'S EXPERIENCE

Dr Sarah Teng
Director, Water Quality Office, PUB, Singapore's National Water Agency

Dr Sarah Teng is the Director of the Water Quality Department of PUB, Singapore's National Water Agency. Her department oversees water quality in the entire water loop in Singapore and drives the comprehensive sampling and monitoring programme from source to taps for over 340 water quality parameters. With Sarah's experience and expertise as a water quality specialist, she also led the team to undertake multidisciplinary research that covers the entire spectrum of microbial and biological contaminants, organic and inorganic chemicals, radionuclides and many other diverse compounds of emerging concern in water. The department under her charge is also the designated WHO Collaborating Centre (WHOCC) for safe management of drinking water and integrated urban water management since January 2012.

DRINKING WATER REGULATIONS IN THE USA AND THE ROLE OF PRODUCT TESTING AND CERTIFICATION

Mr Stan Hazan, MPH
Sr. Director, Science & Regulatory Affairs, NSF International, United States

Mr Stan Hazan is a seasoned public health executive with broad industry experience in the testing, certification and regulatory compliance areas for environmental health related products and services. He has diverse experience in public health, regulatory affairs, marketing, business development, and strategic planning. He supports third party certification programs to the food, water, dietary supplements, environmental, sustainability, consumer products, commercial equipment and management systems industries. He leads legislative and regulatory outreach efforts and works with professional and trade associations to improve quality, safety and environmental compliance. Stan is the principal NSF liaison to EPA, FDA, USDA, CDC and other federal agencies, and to the WHO and Codex Alimentarius. He also serves on the Dean's Advisory Board at the University of Michigan School of Public Health.

PROGRAMME

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DAY 1

23 March 2022, 1:30 - 4:00 UTC
Chair: Professor Zoltan Mester

IMPORTANCE AND CHALLENGES OF ACCURATE MEASUREMENTS ON WATER ANALYSIS

Professor Liandi Ma
Director, Center for Reference Material Research and Management, National Institute of Metrology, China

Professor Ma currently chairs Asia Pacific Metrology Programme (APMP)'s Focus Group on Clean Water. He has been involved in the activities of the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM) and the APMP since 2003. He chaired the APMP's Technical Committee on Amount of Substance from 2015 to 2018. Professor Ma has 30 years of experiences on research in chemical metrology and development of certified reference materials. His research focuses on inorganic and electro-chemical analyses.

BENEFITS OF ACCURACY BASED PROFICIENCY TESTING SCHEMES

Mr Paul McMullen
Sector Manager, Calibration, National Association of Testing Authorities (NATA), Australia

Mr McMullen has a Masters Degree in Applied Science. In the Asia Pacific Accreditation Cooperation (APAC), he is the Convenor of the Reference Materials Working Group under APAC Technical Committee #1, member of the APAC Proficiency Testing Subcommittee and member of the Calibration Working Group. Mr McMullen is a member of the Executive Committee of the Metrology Society of Australasia. He is also a member of the Australian Acoustical Society, member of ISO/CASCO Working Group 57 (currently revising ISO/IEC 17043), and member of the Australian TC-334 (previously REMCO) mirror committee CH-040.

PROGRAMME

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Sydney (Australia): 24 March 2022, 12:30 PM - 3:00 PM

DAY 2

24 March 2022, 1:30 - 4:00 UTC
Chair: Dr Tang Lin Teo

WELCOME ADDRESS

Dr Tang Lin Teo
Division Director, Chemical Metrology Division, Health Sciences Authority (HSA), Singapore

Dr Teo received her PhD in Organic Chemistry from the National University of Singapore. She joined HSA as a Forensic Scientist before she became one of the pioneering members who spearheaded the chemical metrology programme in HSA. Her interests are in certified reference material production, purity assessment of organic compounds, quality management system and analytical methods for the measurement of organic compounds in water, food and biological matrices. Dr Teo is HSA's representative at the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM) and is currently a member of the Executive Committee of the Asia Pacific Metrology Programme.

ANALYTICAL TECHNIQUES USED FOR MEASUREMENTS OF TRACE ELEMENTS IN WATER - PART I

Dr Patricia Grinberg
Research Council Officer, National Research Council (NRC) of Canada

Dr Grinberg received her PhD in Analytical Chemistry at Pontificia Universidade do Rio de Janeiro. She joined the National Research Council Canada first as a guest worker and then as a Research Council Officer. She has broad experience in the field of certified reference material production, analytical chemistry, quality management system and metrology. She is NRC's representative at the Inorganic Analysis Working Group of the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM) of the International Bureau of Weights and Measures (BIPM).

PROGRAMME

Note the local time of some economies in various time zones:
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Sydney (Australia): 24 March 2022, 12:30 PM - 3:00 PM

DAY 2

24 March 2022, 1:30 – 4:00 UTC
Chair: Dr Tang Lin Teo

ANALYTICAL TECHNIQUES USED FOR MEASUREMENTS OF TRACE ELEMENTS IN WATER - PART II

Mr Jeffrey Merrick

Senior Inorganic Chemist, National Measurement Institute, Australia (NMIA)

Mr Merrick graduated with Honours from the University of Sydney in 2006. The following year, he joined NMIA. He is currently the Senior Inorganic Chemist with the Chemical Reference Values section of NMIA. He is primarily responsible for the delivery of high accuracy measurements for certified reference materials, proficiency testing schemes and international comparisons. His work focuses on the measurement of inorganic analytes using ICP-MS and carbon isotope ratios using isotope ratio mass spectrometry.

OBTAINING RELIABLE MEASUREMENT RESULTS FOR ELEMENTS IN WATER - METROLOGICAL TRACEABILITY AND MEASUREMENT UNCERTAINTY

Dr Kyoung-Seok Lee

Head, Inorganic Metrology Group, Division of Chemical and Biological Metrology, Korea Research Institute of Standards and Science (KRISS), Republic of Korea

Dr Lee received his PhD in Physical Chemistry from the Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Republic of Korea. He represents KRISS in the Inorganic Analysis Working Group of the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM) of the International Bureau of Weights and Measures (BIPM), and the Technical Committee for Amount of Substance (TCQM) of the Asia Pacific Metrology Programme (APMP). He has broad experience covering isotope ratio measurements, development of certified reference materials for inorganic analysis, and speciation analysis of organometallic compounds using LC-MS or LC-ICP/MS. He had participated in 18 international comparisons since 2006.

PROGRAMME

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Sydney (Australia): 24 March 2022, 12:30 PM - 3:00 PM

DAY 2

24 March 2022, 1:30 - 4:00 UTC
Chair: Dr Tang Lin Teo

MEASUREMENT UNCERTAINTY IN SAMPLING

Emeritus Professor Michael H. Ramsey
School of Life Sciences, University of Sussex, United Kingdom

Emeritus Professor Ramsey has been Professor at University of Sussex for over 15 years. After a PhD in Analytical Geochemistry, he conducted research and lectured at Imperial College, London for 20 years. He has published over 160 scientific papers, including many on uncertainty of measurement arising from field sampling, and its effects on decision making. Mike is Chair of the Eurachem/Eurolab/CITAC/Nordtest/AMC Working Group on Uncertainty from Sampling, which has published International Guidance on this subject.

ORGANISING COMMITTEE

MEMBERS

DR ANGELA SAMUEL

- Director, International Relations, National Measurement Institute, Australia
- Chair, Developing Economies Committee of the APMP

PROFESSOR ZOLTAN MESTER

- Team Leader, Inorganic Chemical Metrology, National Research Council of Canada
- NRC's representative to SIM

DR TANG LIN TEO

- Division Director, Chemical Metrology Division, Health Sciences Authority, Singapore
- Member of the Executive Committee of the APMP

DR DELLA SIN

- Government Chemist, Government Laboratory of Hong Kong, China
- Co-Convenor, Joint Proficiency Testing Working Group of the APMP & APAC

PROFESSOR PING HE

- Senior Manager, China National Accreditation Service for Conformity Assessment
- Co-Chair, Proficiency Testing Subcommittee of the APAC
- Co-Convenor, Joint Proficiency Testing Working Group of the APAC & APMP
- Convenor, ISO/TC 334 (previously REMCO)/AG2

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- Chair, Focus Group on Food Safety of the APMP

PROFESSOR LIANDI MA

-Director, Center for Reference Material Research and Management, National Institute of Metrology, China
- Chair, Focus Group on Clean Water of the APMP

MR PAUL MCMULLEN

- Sector Manager, Calibration, National Association of Testing Authorities, Australia
- Convenor of the Reference Materials Working Group of the APAC Technical Committee #1

If you have any enquiries, please email us at:
HSA_CML@hsa.gov.sg

ANNEX B

PRE-WORKSHOP SURVEY (PRE-MEASUREMENT WORKSHOP)

Pre-workshop Survey

5 mins estimated time to complete

Instructions

Your feedback will be valuable for the planning of future workshops and related technical activities. The information gathered will be evaluated and presented in aggregate form by the Organising Committee.

Please take a few minutes to complete the following questions.

1. Salutation

(Professor, Dr, Mr, Mdm, Ms, etc)

2. Last name

3. First name

4. Job Title

5. Institute / Laboratory / Company

6. Economy

(Please spell in full, e.g. "Singapore" and not "SG")

7. Email

me@example.com

Accreditation status

8. Are the present services of your institute/laboratory/company in water testing accredited?

- ○ Yes
- ○ Not yet, although we provide water testing services (you may skip Question 9)
- ○ No, although we provide water testing services (you may skip Question 9)
- ○ Not applicable as we do not provide water testing services (you may skip Question 9)

9. What is the current accreditation scope? (optional)

You may select more than one option.

- ☐ Inorganic parameters (e.g. toxic elements)
- ☐ Organic parameters (e.g. pesticides)
- ☐ pH
- ☐ Nutrients (e.g. anions)
- ☐ Micro-organisms
- ☐ Others

If others, please specify.

10. Are you planning to seek accreditation or extend the accreditation scope of your water testing services?

- ○ Yes
- ○ No (you may skip Question 11)
- ○ Not applicable (you may skip Question 11)

11. What is the accreditation scope that you wish to apply for or extend? (optional)

You may select more than one option.

- [ ] Inorganic parameters (e.g. toxic elements)
- [ ] Organic parameters (e.g. pesticides)
- [ ] pH
- [ ] Nutrients (e.g. anions)
- [ ] Micro-organisms
- [ ] Others

If others, please specify.

Participation

12. Do you wish to participate in a proficiency test on “Trace Elements in Natural Water”? The parameters to be measured are arsenic, cadmium, lead and antimony in a matrix of natural mineral water.

Invitation to eligible laboratories will be sent out shortly.

- ( ) Yes
- ( ) No

13. Do you wish to receive further information on a post-measurement workshop that will be held around March 2023?

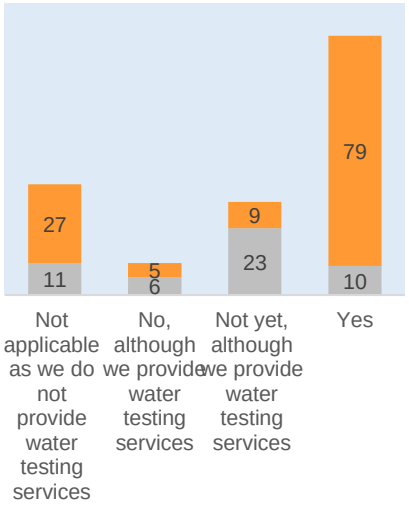
Participation in this workshop will be subject to eligibility criteria, which will be announced later.

- ( ) Yes
- ( ) No

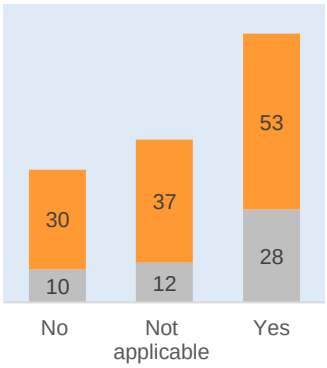
SUBMIT

Based on the survey, 52.4% (89 out of 170) of the respondents are accredited for water testing and 25.3% (43 out of 170) are not, though they are providing services in the area. Another 22.4% (38 out of 170) of the respondents are not providing water testing services. Of the respondents from organisations providing accredited water testing services, 88.8% (79 out of 89) were from APEC economies. The top three accreditation scopes for water testing covered pH, microorganisms and inorganic parameters. The majority, or 47.6% (81 out of 170 respondents) of the respondents shared that they plan to seek accreditation or extend their accreditation scope to cover more areas of water testing. Inorganic analytes were identified as the top parameters in which respondents intend to apply or extend their accreditation scope. See Figure B1a for the survey results.

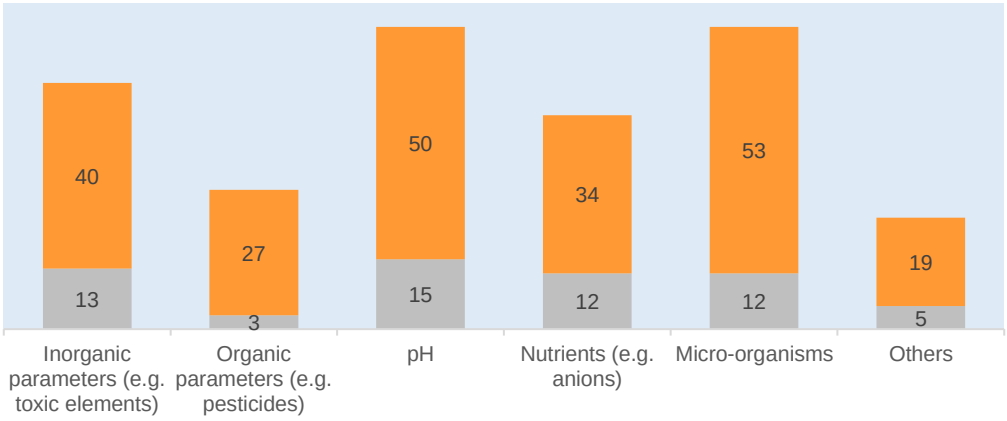
Are the present services of your institute/laboratory/company in water testing accredited?



Are you planning to seek accreditation or extend the accreditation scope of your water testing services?



What is the current accreditation scope?*



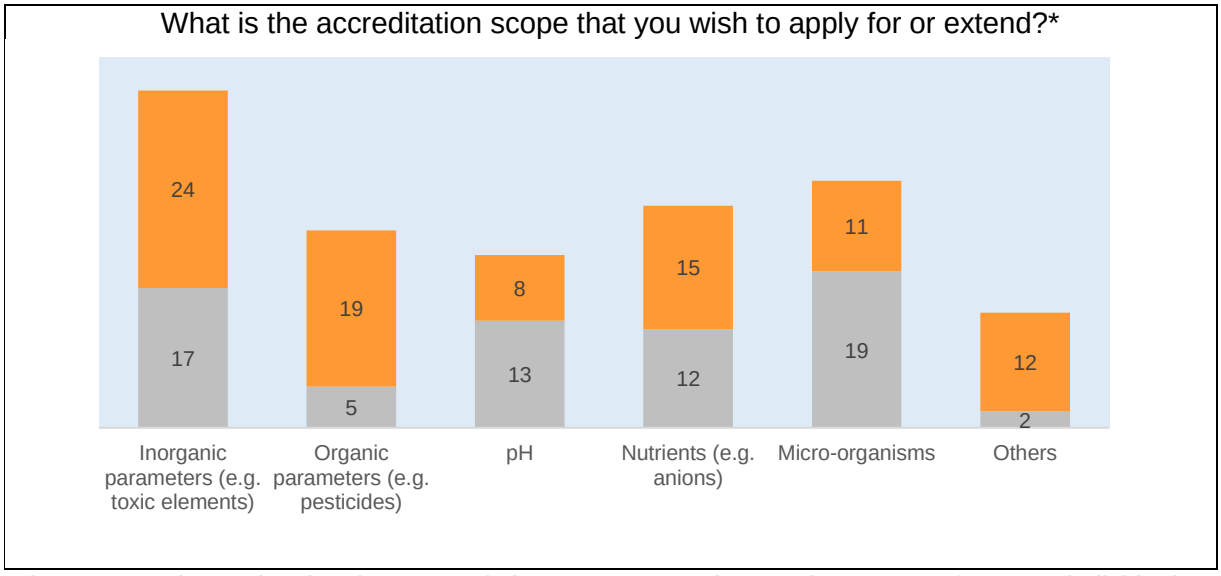


Figure B1a: Charts showing the pre-workshop survey questions and responses from 170 individuals. Data reflecting respondents from APEC and non-APEC economies are coloured in orange and grey, respectively. *Denotes multiple selection was allowed.

A total of 51.2% (87 out of 170) of the respondents expressed their intent to participate in the APEC PT covering arsenic (As), cadmium (Cd), lead (Pb) and antimony (Sb) in natural mineral water. Also, 88.8% (151 out of 170) expressed interest in receiving information about the Post-Measurement Workshop following the completion of the APEC PT (subject to eligibility criteria for participation). See Figure B1b for the survey results.

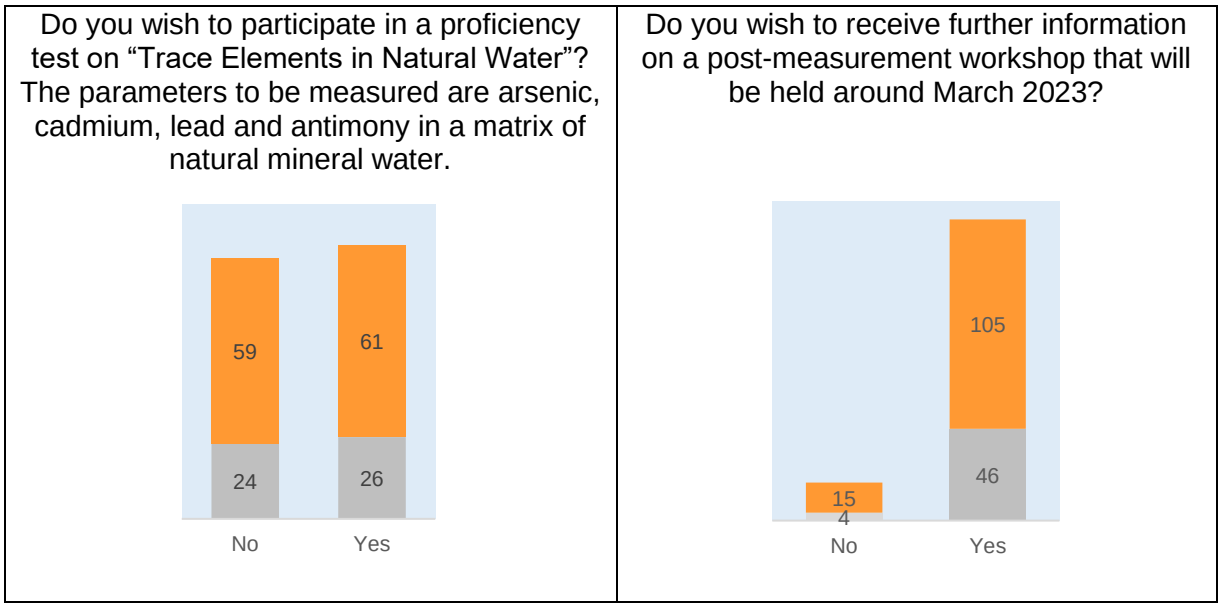


Figure B1b: (Continued) Charts showing the pre-workshop survey questions and responses from 170 individuals. Data reflecting respondents from APEC and non-APEC economies are coloured in orange and grey, respectively.

ANNEX C

PRE-MEASUREMENT WORKSHOP PARTICIPATION AND ONLINE POLL OUTCOMES

The virtual workshop was attended by slightly over 220 attendees on both days. Over 75% of the attendees were from APEC economies. Considering both APEC and non-APEC economies, 64.7% (143 out of 221) and 63.1% (140 out of 222) of the attendees were female at the first and second sessions of the workshop, respectively. The proportion of female attendees was slightly higher (within 2.5%) when only attendees from APEC economies were considered. See Figure C1 for a summary of the profile the attendees at the workshop.

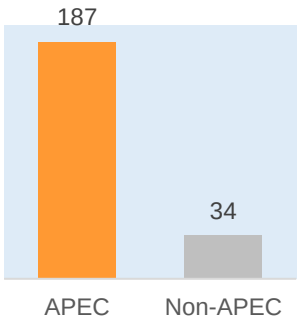
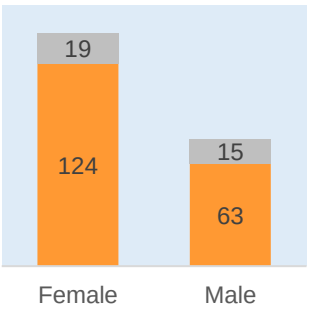
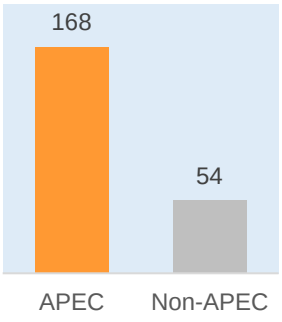
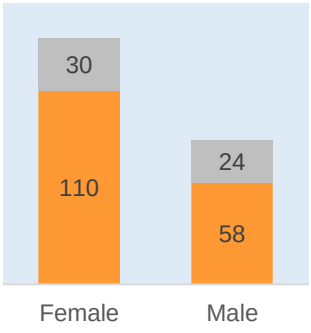
Session	Total number of attendees	Attendees from APEC vs non-APEC economies	Gender profile of attendees from APEC vs non-APEC economies
23 March 2022	221		
24 March 2022	222		

Figure C1: Total number of attendees and their gender profile at the online workshop on 23 & 24 March 2022. Data reflecting attendees from APEC and non-APEC economies are coloured in orange and grey, respectively.

The majority of the attendees were professional laboratory personnel, technical managers or middle management personnel. Attendees comprised individuals with diverse numbers of years of experience in the field of inorganic analysis or measurements. They indicated that they have worked with a range of analytical instruments such as inductively coupled plasma atomic emission spectroscopy (ICP-OES), inductively coupled plasma atomic mass spectrometry (ICP-MS), atomic absorption spectroscopy (AAS) and others for the measurement of the four trace elements, arsenic, cadmium, lead and antimony.

For the attendees whose work involves performing analytical measurements of inorganic elements for customers, the majority of respondents routinely use CRMs as calibrators or quality controls.

While 35.5% (44 out of 124) of the respondents were not previously aware of the differences between accuracy-based and consensus-based PTs, it was encouraging to note that 83.3% (85 out of 102) expressed a preference to participate in an accuracy-based PT after the presentation. See Figure C2 for a summary of the attendees' responses to "live" questions during the workshop.

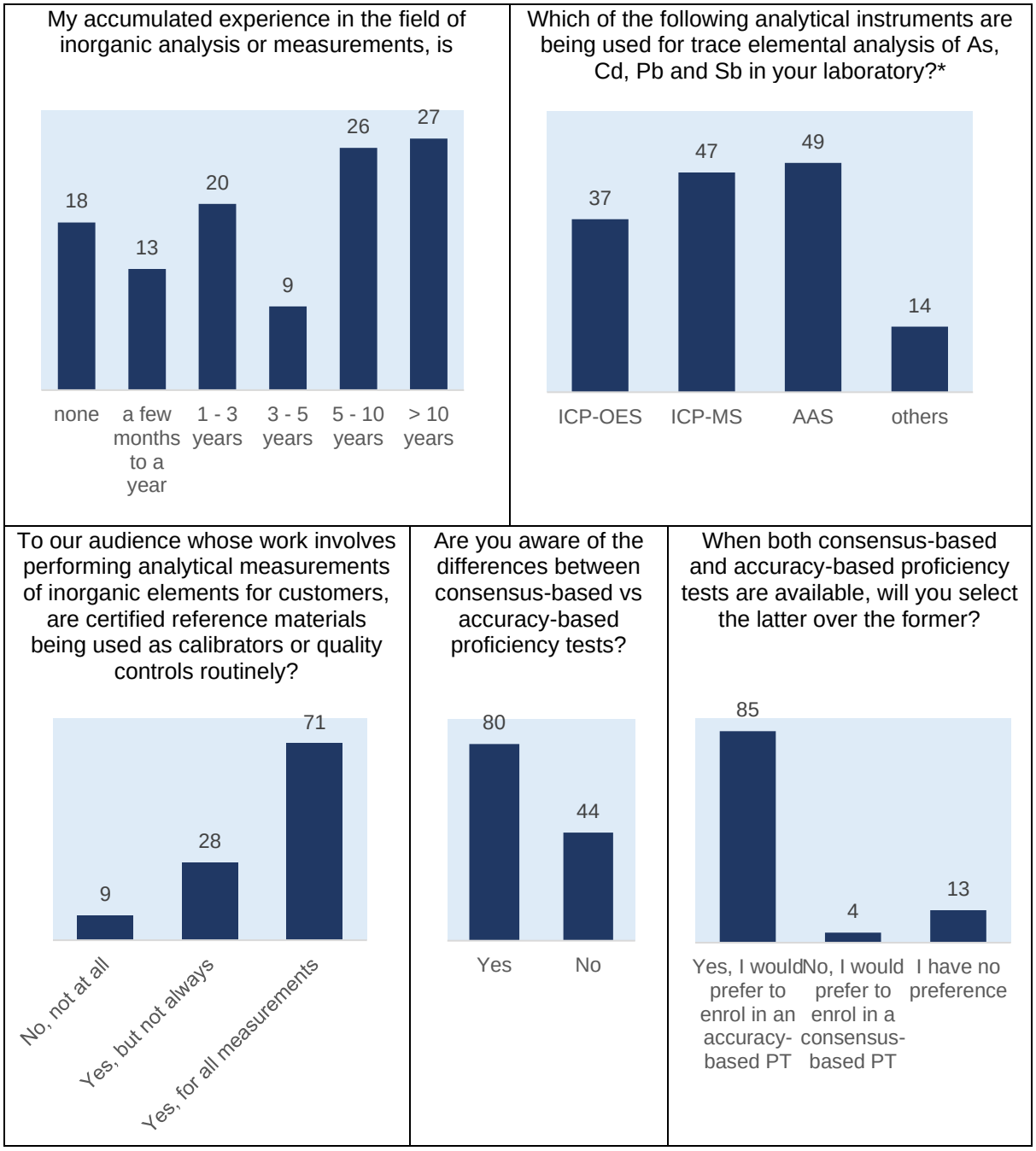
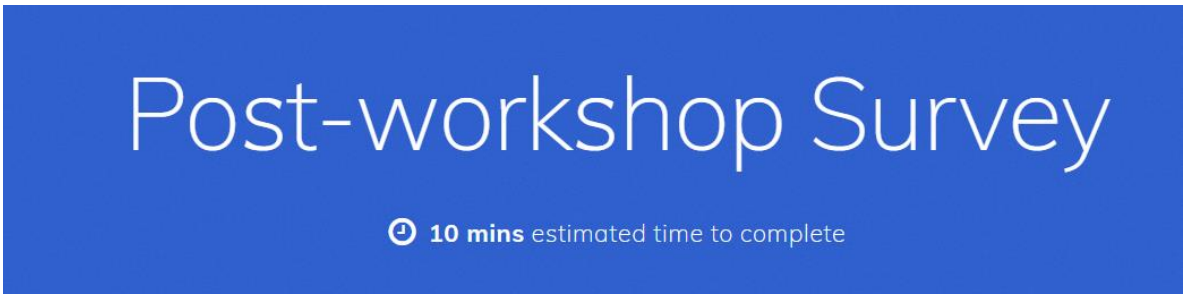


Figure C2: Attendees' responses to "live" questions during the workshop. The responses are analysed collectively and are not differentiated according to APEC or non-APEC economies. *Denotes multiple selection was allowed.

ANNEX D

POST-WORKSHOP SURVEY (PRE-MEASUREMENT WORKSHOP)



Instructions

Thank you for attending the online workshop titled "Making an impact on water quality for public health and safety - Workshop on building laboratory measurement techniques" held on 23 & 24 March 2022.

Your evaluation is important in helping us assess this workshop, improve our project quality and plan our next steps.

Please take a few minutes to complete the following questions.

1. Salutation

(Professor, Dr, Mr, Mdm, Ms, etc)

2. Last name

3. First name

4. Job title

5. Institute / Laboratory / Company

6. Economy

(Please spell in full, e.g. "Singapore" and not "SG")

7. Email

me@example.com

8. Gender

- Female
- Male

9. I attended the workshop on

- 23 March 2022 / Day 1
- 24 March 2022 / Day 2
- Both 23 and 24 March 2022 / Day 1 and 2

10. How relevant were the topics covered in this workshop to you and your economy?

- Very relevant
- Mostly relevant
- Somewhat relevant
- A little relevant
- Not relevant

11. Please rate your level of knowledge and/or technical know-how in the topics prior to attending the workshop.

- Very good
- Good
- Well
- Fair
- Poor

12. Please rate your level of knowledge and/or technical know-how in the topics after attending the workshop.

- ○ Very good
- ○ Good
- ○ Well
- ○ Fair
- ○ Poor

13. The objectives of the workshop were clearly defined.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Disagree
- ○ Strongly disagree

14. The workshop has achieved its intended objectives.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Disagree
- ○ Strongly disagree

15. The topics covered in the workshop were relevant to my work.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Disagree
- ○ Strongly disagree

16. The speakers were well prepared and knowledgeable about the topics that they have covered.

- Strongly agree
- Agree
- Somewhat agree
- Disagree
- Strongly disagree

17. The materials presented in the workshop were sufficient given the timeframe allocated.

- Strongly agree
- Agree
- Somewhat agree
- Disagree
- Strongly disagree

18. The time allocated for each topic was reasonable and the programme was well paced.

- Strongly agree
- Agree
- Somewhat agree
- Disagree
- Strongly disagree

19. The platform used for the workshop was user-friendly, it allowed me to interact with the speakers and panelists, and I did not encounter technical issues with using it.

- Strongly agree
- Agree
- Somewhat agree
- Disagree
- Strongly disagree

20. How would you apply the knowledge learnt from the workshop to your work?

You may select more than one option.

- [ ] Participation in international/regional comparison
- [ ] Participation in APEC proficiency test
- [ ] Participation in other proficiency tests
- [ ] Development of new policy initiatives
- [ ] Development of new work plans or strategies
- [ ] Development of new in-house training materials
- [ ] Development of new procedures or tools
- [ ] Improve existing procedures or tools
- [ ] Others

If others, please specify.

21. Please select which fora your institute/laboratory/company would like to participate in to demonstrate your measurement capability:

- ( ) Supplementary comparison organsied by the Inter-American Metrology System (SIM) - for metrology institutes only
- ( ) Pilot study organised by the Asia Pacific Metrology Programme (APMP) - for metrology institutes only
- ( ) APEC proficiency test
- ( ) None of the above

22. Please leave us other comments, if any. (optional)

SUBMIT

Based on the survey, 84.0% (157 out of 187) of all respondents attended the workshop on both days, with 90.9% (170 out of 187) finding the Workshop topics to be mostly or very relevant to themselves or their economies. The majority or 62.6% (117 out of 187) of them rated their level of knowledge/technical know-how before the Workshop as “well” or “good” on the topics; this rose to 84.0% (157 out of 187) rating themselves as “good” or “very well” after attending the event. See Figure D1a.

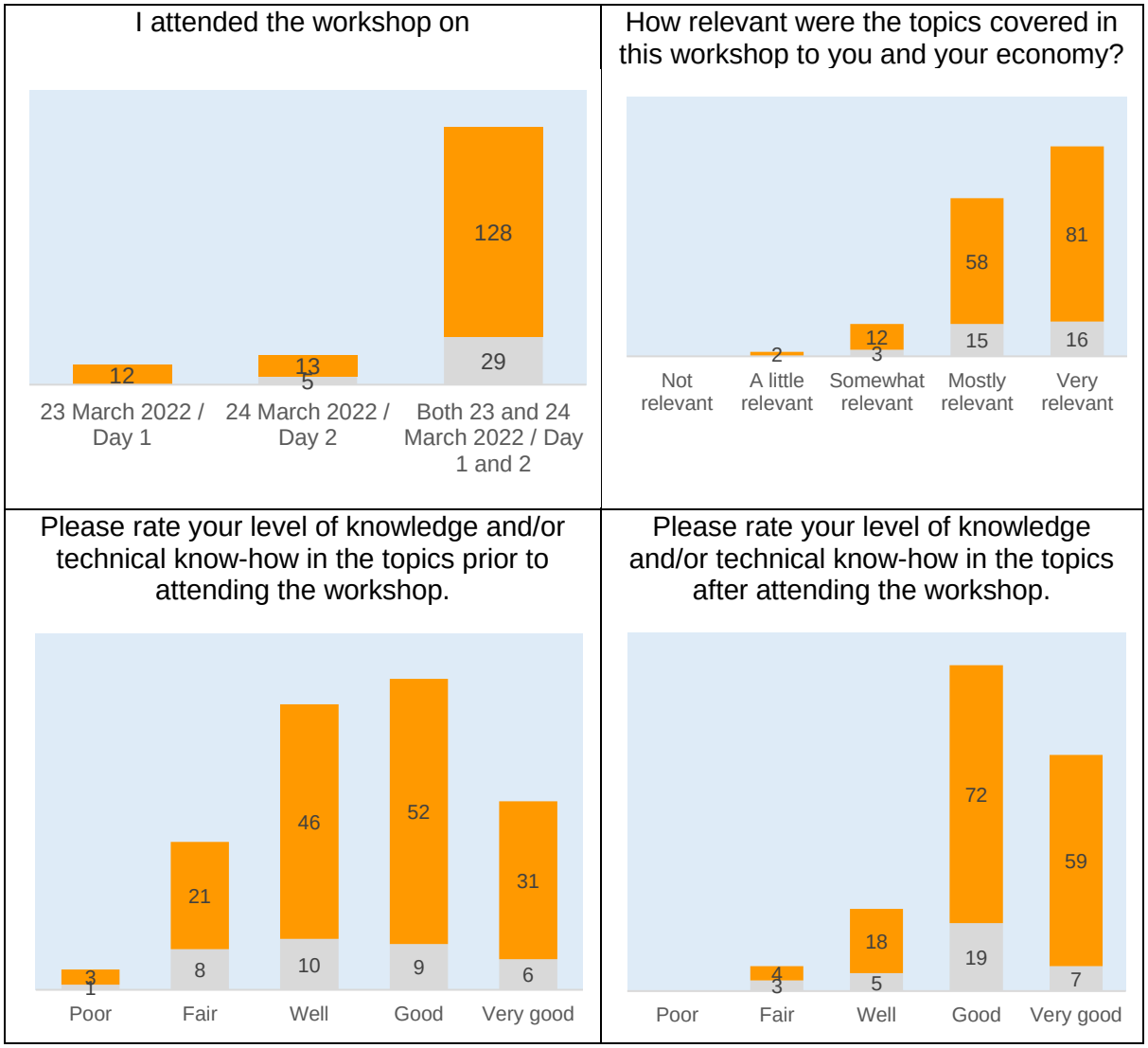


Figure D1a: Charts showing the post-workshop survey questions and responses from 187 individuals. Data reflecting respondents from APEC and non-APEC economies are coloured in orange and grey, respectively.

Over 89.3% (and up to 98.9%) of the attendees agreed or strongly agreed that the objectives of the workshop were clearly defined, well covered and achieved its intended objectives; the speakers had provided sufficient materials and they were well prepared and knowledgeable; the workshop was well-paced; and the selected platform was user-friendly and allowed interactions with the speakers. See Figures D1b and D1c.

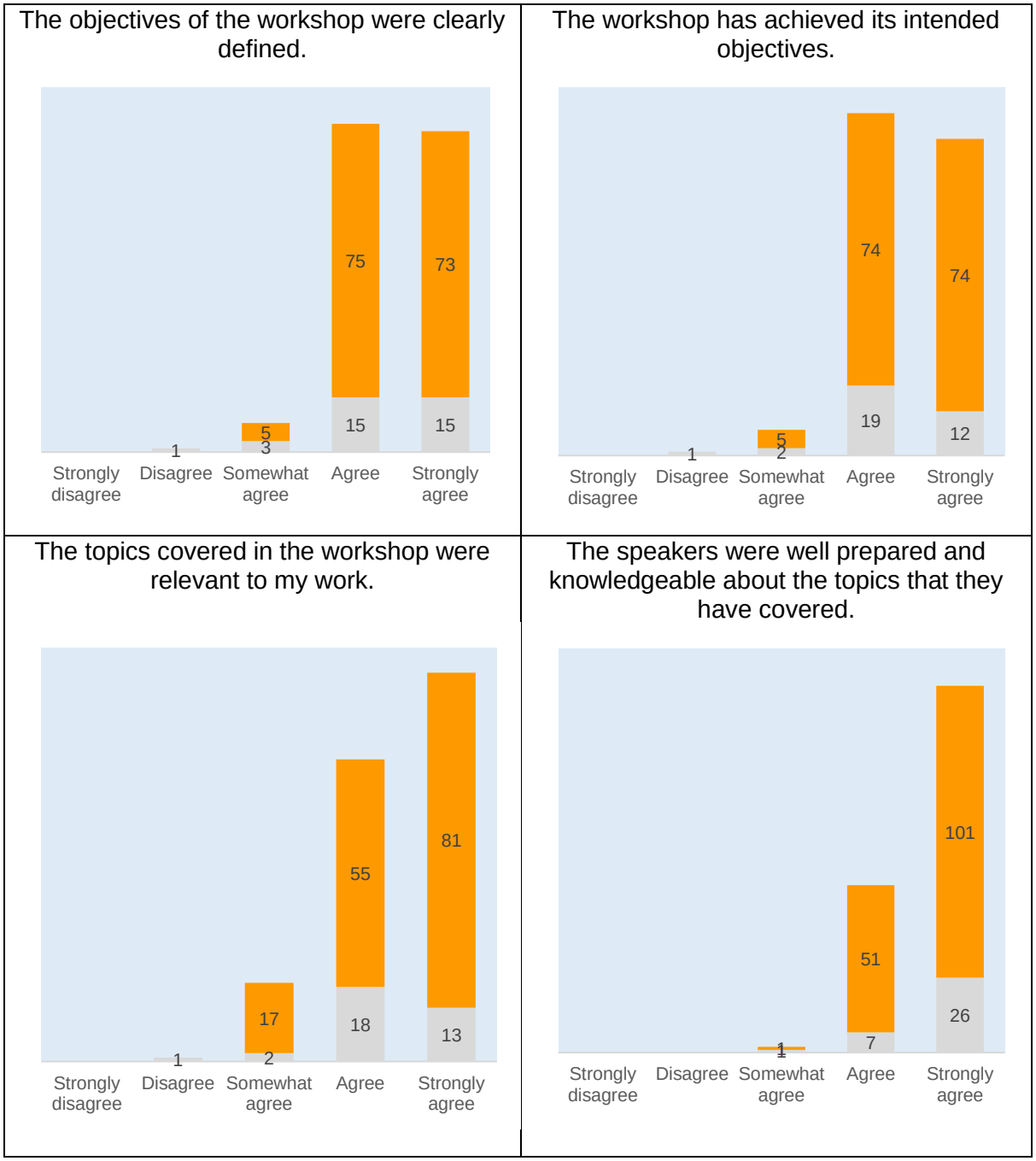
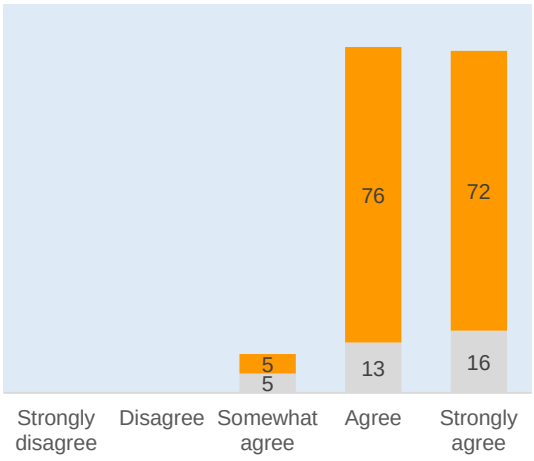
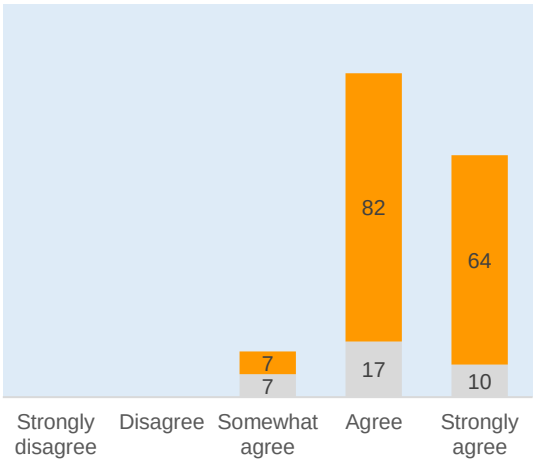


Figure D1b: (Continued) Charts showing the post-workshop survey questions and responses from 187 individuals. Data reflecting respondents from APEC and non-APEC economies are coloured in orange and grey, respectively.

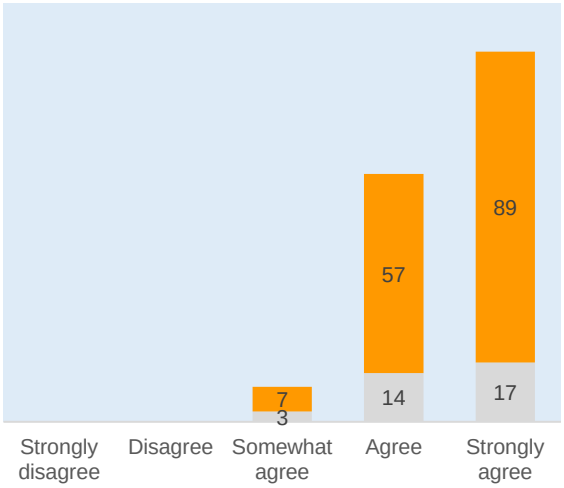
The materials presented in the workshop were sufficient given the timeframe allocated.



The time allocated for each topic was reasonable and the programme was well paced.



The platform used for the workshop was user-friendly, it allowed me to interact with the speakers and panelists, and I did not encounter technical issues with using it.



Please select which fora your institute/laboratory/company would like to participate in to demonstrate your measurement capability*:

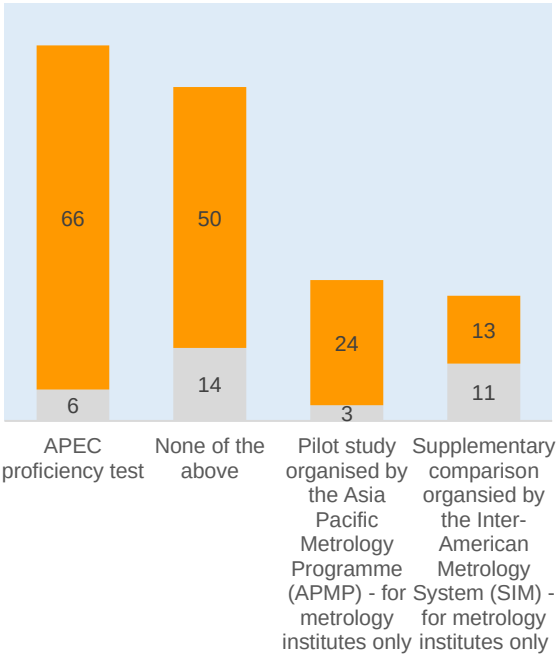


Figure D1c: (Continued) Charts showing the post-workshop survey questions and responses from 187 individuals. Data reflecting respondents from APEC and non-APEC economies are coloured in orange and grey, respectively. *Denotes multiple selection was allowed.

It was encouraging to learn that attendees intend to apply the knowledge acquired from the workshop to improving existing procedures or tools in their work; development of new in-house training materials, work plans or strategies; and participation in PTs. See Figure D1d.

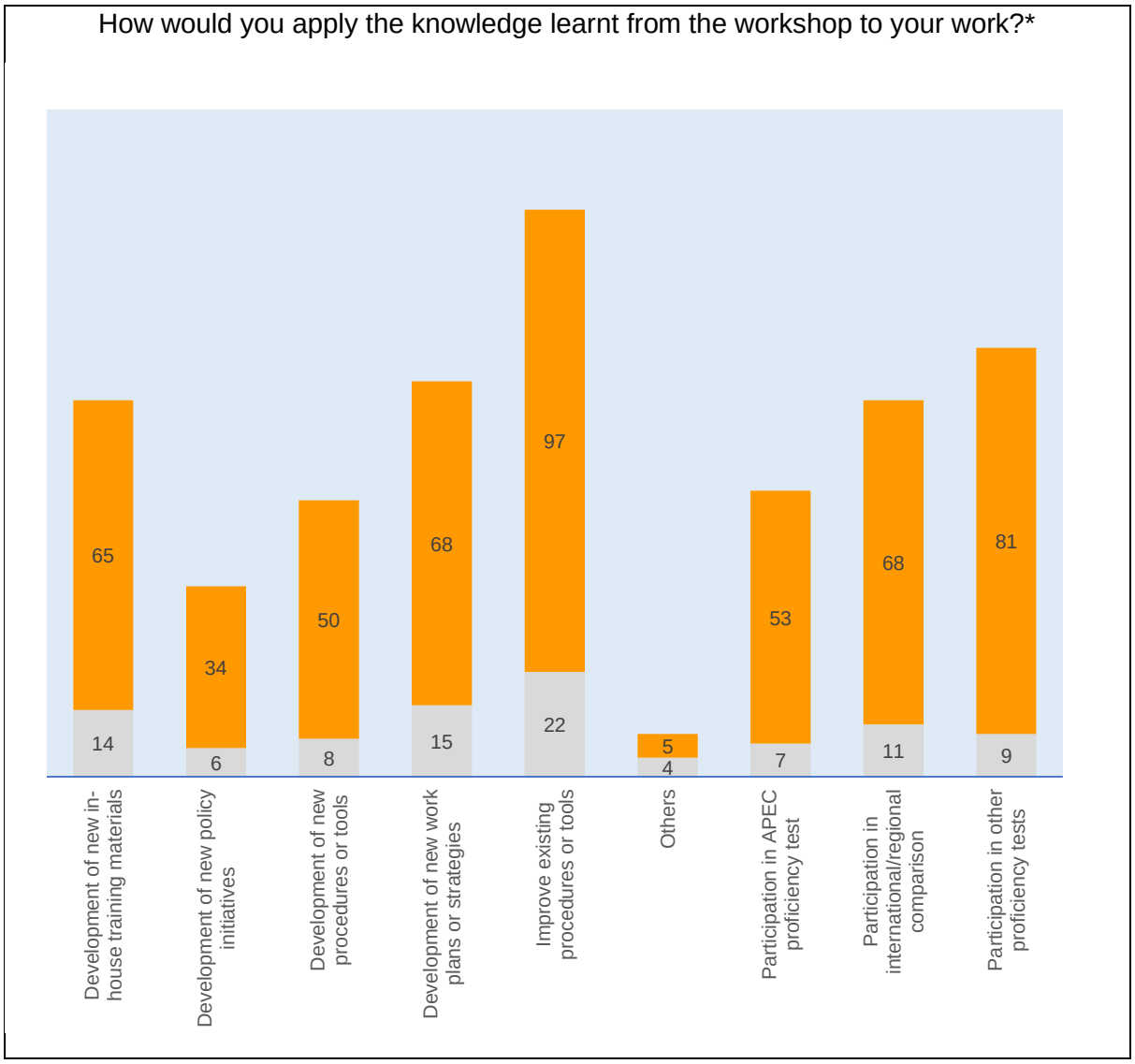


Figure D1d: (Continued) Charts showing the post-workshop survey questions and responses from 187 individuals. Data reflecting respondents from APEC and non-APEC economies are coloured in orange and grey, respectively. *Denotes multiple selection was allowed.

ANNEX E

APEC PT PROTOCOL

APEC Proficiency Testing Scheme

Trace Elements in Natural Water

Asia-Pacific Economic Cooperation Proficiency Testing Scheme (APEC PT)

Trace Elements in Natural Water

Protocol

Coordinated by

Government Laboratory, Hong Kong (GLHK)

7/F., Homantin Government Offices

88 Chung Hau Street, Homantin, Kowloon

Hong Kong, China

March 2022

Asia-Pacific Economic Cooperation

APEC Proficiency Testing Scheme

Trace Elements in Natural Water

APEC Proficiency Testing Scheme: Trace Elements in Natural Water

1. Introduction

Water quality is a priority for all economies and underpins food security, agriculture, health, and trade facilitation – all ongoing priorities for Asia-Pacific Economic Cooperation (APEC). The "APEC Food Security Roadmap Towards 2030" was launched in 2021 to support inclusive, resilient and sustainable recovery of the APEC region. Goal 6 of the UN Sustainable Development Goals, availability and access to water, sanitation and hygiene (WASH) services is fundamental in maintaining public health and in the fight against COVID-19. The 2021 World Water Development Report on "Valuing Water" also identifies that a solid technical infrastructure is required to obtain good and reliable measurement data to make educated social, economic, and environmental decisions by all levels of governance. The need for traceable measurements supporting water quality policies has also been identified and supported under the European Water Framework.

With a view to help build laboratories capacities in the APEC region, a project entitled "Building laboratory capabilities to assure water quality in Asia-Pacific Economies (APEC Project SCSC 01 2021)" was approved. Experts in chemical measurement from the Asia Pacific Metrology Programme (APMP) will work with colleagues from the Inter-American Metrology System (SIM) (APMP's counterpart in the Americas) to provide oversight and management of the project. Workshops will be organized for knowledge sharing with laboratory staff to measure parameters affecting water quality and sanitation. Experts from the Asia Pacific Accreditation Cooperation (APAC) will also provide advice and support to the project. By helping laboratories achieve comparability through internationally recognized measurement and accreditation frameworks, the project will increase the sustainability of benefits for all economies across the Asia-Pacific region and beyond.

The participating measurement institutes/laboratories in this APEC PT scheme will be expected to measure parameters affecting water quality. The PT will help assess uptake of the knowledge and training from the Preparatory Workshop of the APEC Project and evaluate the measurement capabilities of participating institutes and laboratories. Metrologically traceable results will be used to benchmark the performance of participants. PT participants will also be invited to attend a Post-Measurement Workshop to share experience, identify further needs and develop action plans for improving laboratory practices and capabilities. Particular attention will be paid to the design and facilitation of the workshop to ensure that technical personnel involved in the actual measurements reflect on the learning outcomes from the project; identify needs for further support and skills development; and are able to implement their institute's action plans in their respective economies. The details of

the two workshops including registration, dates and venues will be announced separately.

2. Objectives

This PT scheme targets the analysis of four elements (antimony, arsenic, cadmium and lead) spiked in a natural water sample. The objectives of the scheme are (i) to assist participating laboratories in demonstrating competence on the measurement of the mass fractions of the analytes in the sample by various analytical techniques; and (ii) to identify problems and opportunities for further improvement. The mass fractions of the analytes reported on an as-received basis will be used for comparability purposes.

3. Proficiency testing provider

The APEC PT is organized by the Government Laboratory, Hong Kong (GLHK) (Address: 7/F., Homantin Government Offices, 88 Chung Hau Street, Homantin, Kowloon, Hong Kong, China). GLHK takes responsibility for all tasks in the development and operation of the PT scheme, including preparation and distribution of PT samples, data analysis and evaluation of results, preparation of interim and final reports, and communications with participants.

4. Fee for participation

Participation in the PT scheme is free of charge.

Participants are responsible for responding to their local customs and couriers to ensure prompt receipt of the PT sample, which may not be replaced if there are damages after the participating laboratories have acknowledged receipt of the PT samples in good order.

5. Selection of participants

Eligible laboratories will be invited to participate in the PT scheme through the APEC Sub-Committee on Standards and Conformance (SCSC), APAC, APMP and SIM's contact networks. It is anticipated that about 100 water measurement laboratories mainly from APEC member economies will join the PT scheme.

6. Proficiency test sample

The source of the study material was commercially available natural mineral groundwater from Fanjing Mountain, World Natural Heritage, China. The study material was prepared by GLHK in middle September 2021. An acid-cleaned HDPE tank of 60 L capacity was filled with approximately 40 L of natural mineral water and concentrated nitric acid was added to adjust the acid volume fraction to approximately 2%. A preliminary ICP-MS analysis was performed to determine the levels of the elements of interest. The levels of As, Cd, Pb and Sb were gravimetrically adjusted by

additions of aliquots of known masses of single-element standard solutions. After thorough mixing with a mechanical stirrer for 2 h, an inductively coupled plasma mass spectrometry (ICP-MS) analysis was performed to confirm that the levels of the 4 elements of interest are within the target ranges. The sample solutions were packaged into pre-cleaned amber HDPE bottles of 250 mL capacity and sealed inside aluminized Mylar pouches. About 180 bottles of sample were prepared. Each bottle contains at least 200 mL of sample solution.

Randomly selected bottles were assessed for homogeneity. ANOVA at 95% level of confidence will be applied to assess the between-bottle homogeneity in accordance with ISO Guide 35:2017.

The short-term stability of the measurands over a period of 4 weeks at 60 °C was assessed using isochronous approach. Two randomly selected sample bottles were transferred from the storage condition at 4 °C to 60 °C on three occasions (2, 4 and 6 weeks) over the study period. Two subsamples were then taken from each bottle and analyzed by ICP-MS. Using the student's *t*-test on the slope of the linear regression at 95% level of confidence, no significant instability of the measurands was observed.

The long-term stability of the measurands in the comparison material at 4 °C will be assessed. The testing will be carried out before sample dispatch and continuously monitored until completion of the PT scheme using the classical approach. For each occasion of the stability testing, at least two bottles will be randomly selected, and two subsamples will be taken from each bottle. Student's *t*-test on the slope of the linear regression at 95% level of confidence will be used for the evaluation of instability of the measurands.

7. Instructions for participants

Each participant will receive one bottle of the sample containing at least 200 mL of sample. The samples will be distributed by courier to the participants (monitored by a temperature strip). Participants will be informed and provided with the tracking number after sample dispatch. Upon receipt, the samples should be stored at 4 °C. A Sample Receipt Form will be provided to the participating institutes for completion. The completed form should be sent to the organizer at the earliest convenience.

Samples should be shaken before use to account for any possible water condensation on the inner surfaces of the bottle. To avoid possible contamination, do not insert pipettes or other apparatus into the bottle. Samples should be treated at room temperature around 15 ºC to 25 ºC before use. To prevent evaporation loss, the bottle should be recapped tightly and returned to the aluminized plastic bag, which should be folded and sealed with sealing tape after use. Participants may check for any evaporation issues by weighing the bottle before and after taking sample aliquots between storage.

Participants may use any test method of their choice. The recommended minimum sample amount for analysis is 5 grams. The bottle contents should be well mixed by rotation and shaking prior to use. Participants are requested to perform at least three independent measurements on three separate portions of the sample and to determine the mass fractions of the analytes. The four measurands and the range of values expected are given in Table 1.

Table 1

Element	Expected mass fraction	Natural/Spiked	Description
Arsenic (As)	(0.1–30) µg/kg	Spiked	Toxic element
Cadmium (Cd)	(0.1–30) µg/kg	Spiked	Toxic element
Antimony (Sb)	(0.1–30) µg/kg	Spiked	Metalloid
Lead (Pb)	(0.1–30) µg/kg	Spiked	Toxic element

It is not necessary to return the untested portion of the PT sample to the organizer.

8. Reporting and submission of results

Participants should complete the Result Proforma (Annex A). The manner of reporting test results is as follows:

- For each analyte, the mean value of at least 3 independent measurements and its associated uncertainty (combined standard uncertainty at 1 sigma level) should be reported;
- Report the mass fractions of analytes in µg/kg; and
- Participants should provide information about the methods of analysis.

Participants should be aware that any submitted results are considered final. Therefore, results and units of measurement should be thoroughly checked before submission. Participants should submit the Result Proforma electronically to the co-ordinator of the PT scheme (E-mail: apccpt2022@govtlab.gov.hk) on or before the end of September 2022. Results submitted after the deadline will not be accepted. Participants are reminded that the ability to report results in the specified unit and within the given time scale are part of the PT.

9. Measurement uncertainty

Measurement uncertainty is best estimated within the individual laboratory environment. An estimate of uncertainty of measurement is normally based on the combination of a number of influencing parameters (components of uncertainty) such as errors in reference values, instrument errors, repeatability, thermal effects, weighing errors, inhomogeneity etc. As stipulated in ISO Guide to the Expression of Uncertainty in Measurement, the influence of each component of uncertainty on the measurement result should be quantified and expressed numerically as a standard deviation. These values are then combined according to the rules of the propagation of uncertainty to produce a combined standard deviation (combined standard uncertainty) and the combined standard uncertainty is multiplied by a coverage factor to produce an expanded uncertainty at the required level of confidence.

10. Evaluation of performance of participants

Performance of the participating laboratories is assessed using z-score, which is calculated as follows:

$$z_i = \frac{x_i - x_{pt}}{\sigma_{pt}}$$

where x_i : the participant's result
x_{pt} : the assigned value
σ_{pt} : the standard deviation for proficiency assessment estimated from the Horwitz equation

Note: The reference values measured by NMIs/DIs with the support of CMC claims will be used as the assigned values. This is in accordance with the ISO/IEC 17043 and ISO 13528 recommendations on the determination of assigned values for proficiency testing schemes.

The z-score is commonly interpreted as:

(i)	$\|z\| \leq 2$	Satisfactory
(ii)	$2 < \|z\| < 3$	Questionable
(iii)	$\|z\| \geq 3$	Unsatisfactory

Laboratories having a |z| score equal to or larger than 3 shall thoroughly investigate their results for the discrepancy and those having a z-score in the range $2 < |z| < 3$ are also encouraged to review their results.

For reference purpose, the performance of the participating laboratories will also be assessed using zeta-score (ζ), which is calculated as:

$$\zeta_i = \frac{x_i - x_{pt}}{\sqrt{u^2(x_i) + u^2(x_{pt})}}$$

where x_i = the participant's result
x_{pt} = the assigned value
$u(x_i)$ = the participant's estimate of the standard uncertainty of its result x_i
$u(x_{pt})$ = the standard uncertainty of the assigned value x_{pt}

ζ-score is interpreted in the same way as z-score using the critical values of 2.0 and 3.0. ζ-score may be used in conjunction with z-score, as an aid for improving the performance of laboratories. If participating laboratories obtain a |z| score that exceed 3.0, they may find it of value to examine their test procedure step by step and derive an uncertainty budget for that procedure. The uncertainty budget will identify the steps in the procedure where the largest uncertainties arise, so that the laboratories can see where to expend effort to achieve an improvement. If the |ζ| score also exceeds the critical value of 3.0, it implies that the uncertainty budget does not include all significant sources of uncertainty. The laboratories are encouraged to review their uncertainty budget.

11. Issuing of reports

An interim report will be issued to participants to check the correctness of results submitted. The draft final report will then be prepared and submitted to APEC SCSC for comments and approval. Upon approval, an electronic copy of the final report will be distributed to participants.

The final report, part of the final report or its summary may be posted on the APEC website for public interest.

12. Confidentiality

The responsible parties will strive to maintain strict confidentiality with respect to the composition of the PT sample distributed and the performance of all participating laboratories. To preserve confidentiality, participants receive reports giving all results for assessment but without identifying individual laboratories. The code number assigned to a participant in the PT scheme is only made known to the contact person/authorized person of the participating laboratory.

The PT scheme is conducted on the understanding that participants will perform the analysis and report results with scientific rigour. Collusion and falsification of results are clearly against the spirit of the PT scheme.

13. Proposed schedule

The proposed schedule for the PT scheme (APEC PT) is as follows:

Proposed schedule	**Phase**
Late March 2022	Call for participation
23 April 2022	Deadline for registration
May – September 2022	Distribution of samples, measurements undertaken and results submitted
September – December 2022	Review of results /issue of interim PT report
April 2023	Issue of the final PT report

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Trace Elements in Natural Water

14. Intellectual Property

The PT organizer will provide APEC with information on the analytical methods used by the participants, results, etc in the Final PT Report, for which APEC will own the copyright. If you have any enquiries about this, please feel free to contact us.

15. Contact

Contact information have been removed prior to generation of the PT Final report.

16. References

16.1 ISO/IEC 17000:2004, Conformity assessment – Vocabulary and general principles

16.2 ISO/IEC Guide 99:2007, International vocabulary of metrology – Basic and general concepts and associated terms (VIM)

16.3 ISO/IEC 17043:2010 "Conformity assessment – General requirements for proficiency testing", 2010, Geneva, Switzerland.

16.4 ISO 13528:2015 "Statistical methods for use in proficiency testing by interlaboratory comparison", 2015, Geneva, Switzerland.

16.5 ISO 17034:2016 "General requirements for the competence of reference material producers", 2016, Geneva, Switzerland.

16.6 ISO Guide 35:2017 "Reference materials – Guidance for characterization and assessment of homogeneity and stability", 2017, Geneva, Switzerland.

16.7 W. Horwitz. Evaluation of analytical methods used for regulations of food and drugs, Anal. Chem. 1982, 54:67A-76A.

16.8 The International Harmonized Protocol for the Proficiency Testing of Analytical Chemistry Laboratories, Pure Appl. Chem. 2006, 78, 1, 145-196.

16.9 CODEX STAN 193-1995 "Codex General Standard for Contaminants and Toxins in Food and Feed", 2016, CODEX Alimentarius.

16.10 ISO/IEC Guide 98-3:2008 "Uncertainty of measurement -- Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)", 2008, Geneva, Switzerland.

16.11 Guidelines for drinking-water quality: fourth edition incorporating the first addendum, Geneva, World Health Organization; 2017. ISBN-13: 978-92-4-154995-0.

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Annex A

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Result Proforma

Institute/ Laboratory: _____

Contact person: _____ _____ _____

Title Given name Surname

E-mail: _____

Print name / Signature: _____

Date: _____

1. Analytical results

Analyte	Number of subsamples (n)	Mean value (μg/kg)	Combined standard uncertainty (μg/kg)	Coverage factor *k* (95% level of confidence)	Expanded uncertainty (μg/kg)
As					
Cd					
Sb					
Pb					

Notes: (i) Report the analytical results and associated uncertainty in μg/kg;
(ii) Report values with 3 significant figures.

Please complete this form and return it to the coordinator of the proficiency testing scheme (email: apecpt2022@govtlab.gov.hk) on or before ***30 September 2022****.*

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2. Methods of analysis (As)

*Method accreditation: Yes / No

Sample amount used for analysis: _____

*Sample treatment: No treatment / Dilution / Wet digestion / Microwave-assisted digestion / Others (please specify): _____

*Analytical Instrument(s): ICP-MS / ICP-OES / Flame AAS / Others (please specify): _____

* Quantification technique: External calibration / Internal calibration / Standard additions / Others (please specify): _____

Calibration standard: _____

Internal standard (if any): _____

Matrix CRM or QC sample (if any): _____

Recovery of matrix CRM / QC (%): _____

*Correction for recovery: Yes / No

Additional information / Sources of MU / Any abnormal observations and problems encountered during analysis:

_____

_____

_____

* Please delete as appropriate

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Trace Elements in Natural Water

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Trace Elements in Natural Water

3. Methods of analysis (Cd)

*Method accreditation: Yes / No

Sample amount used for analysis: _____

*Sample treatment: No treatment / Dilution / Wet digestion / Microwave-assisted digestion
Others (please specify): _____

*Analytical Instrument(s): ICP-MS / ICP-OES / Flame AAS / Others (please specify): _____

* Quantification technique: External calibration / Internal calibration / Standard additions / IDMS /
Others (please specify): _____

Calibration standard: _____

Internal standard (if any): _____

Matrix CRM or QC sample (if any): _____

Recovery of matrix CRM / QC (%): _____

*Correction for recovery: Yes / No

Additional information / Sources of MU / Any abnormal observations and problems encountered during analysis:

_____

_____

_____

* Please delete as appropriate

APEC Proficiency Testing Scheme

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Trace Elements in Natural Water

4. Methods of analysis (Sb)

*Method accreditation: Yes / No

Sample amount used for analysis: _____

*Sample treatment: No treatment / Dilution / Wet digestion / Microwave-assisted digestion
Others (please specify): _____

*Analytical Instrument(s): ICP-MS / ICP-OES / Flame AAS / Others (please specify): _____

* Quantification technique: External calibration / Internal calibration / Standard additions / IDMS /
Others (please specify): _____

Calibration standard: _____

Internal standard (if any): _____

Matrix CRM or QC sample (if any): _____

Recovery of matrix CRM / QC (%): _____

*Correction for recovery: Yes / No

Additional information / Sources of MU / Any abnormal observations and problems encountered during analysis:

_____

_____

_____

* Please delete as appropriate

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Trace Elements in Natural Water

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Trace Elements in Natural Water

5. Methods of analysis (Pb)

*Method accreditation:	Yes / No
Sample amount used for analysis:	_____
*Sample treatment	No treatment / Dilution / Wet digestion / Microwave-assisted digestion Others (please specify):
*Analytical Instrument(s):	ICP-MS / ICP-OES / Flame AAS / Others (please specify):
* Quantification technique:	External calibration / Internal calibration / Standard additions / IDMS / Others (please specify):
Calibration standard:	_____
Internal standard (if any):	_____
Matrix CRM or QC sample (if any):	_____
Recovery of matrix CRM / QC (%):	_____
*Correction for recovery:	Yes / No

Additional information / Sources of MU / Any abnormal observations and problems encountered during analysis:

_____

_____

_____

* Please delete as appropriate

--- End --

ANNEX F

APEC PT SAMPLE RECEIPT FORM

Asia-Pacific Economic Cooperation

APEC Proficiency Testing Scheme

Trace Elements in Natural Water

Result Proforma

Institute/ Laboratory: _____

Contact person: _____ _____ _____

Title Given name Surname

E-mail: _____

Print name / Signature: _____

Date: _____

1. Analytical results

Analyte	Number of subsamples (n)	Mean value (µg/kg)	Combined standard uncertainty (µg/kg)	Coverage factor *k* (95% level of confidence)	Expanded uncertainty (µg/kg)
As					
Cd					
Sb					
Pb					

Notes: (i) Report the analytical results and associated uncertainty in µg/kg;

(ii) Report values with 3 significant figures.

Please complete this form and return it to the coordinator of the proficiency testing scheme (email: apecpt2022@govtlab.gov.hk) on or before ***30 September 2022****.*

ANNEX G

APEC PT RESULT PROFORMA

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APEC Proficiency Testing Scheme

Trace Elements in Natural Water

Result Proforma

Institute/ Laboratory: _____

Contact person: _____ _____ _____

Title Given name Surname

E-mail: _____

Print name / Signature: _____

Date: _____

1. Analytical results

Analyte	Number of subsamples (n)	Mean value (µg/kg)	Combined standard uncertainty (µg/kg)	Coverage factor *k* (95% level of confidence)	Expanded uncertainty (µg/kg)
As					
Cd					
Sb					
Pb					

Notes: (i) Report the analytical results and associated uncertainty in µg/kg;

(ii) Report values with 3 significant figures.

Please complete this form and return it to the coordinator of the proficiency testing scheme (email: apecpt2022@govtlab.gov.hk) on or before ***30 September 2022****.*

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2. Methods of analysis (As)

*Method accreditation: Yes / No

Sample amount used for analysis: .....

*Sample treatment: No treatment / Dilution / Wet digestion / Microwave-assisted digestion
Others (please specify): .....

*Analytical Instrument(s): ICP-MS / ICP-OES / Flame AAS / Others (please specify): .....

* Quantification technique: External calibration / Internal calibration / Standard additions /
Others (please specify): .....

Calibration standard: .....

Internal standard (if any): .....

Matrix CRM or QC sample (if any): .....

Recovery of matrix CRM / QC (%): .....

*Correction for recovery: Yes / No

Additional information / Sources of MU / Any abnormal observations and problems encountered during analysis:

.....

.....

.....

* Please delete as appropriate

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Trace Elements in Natural Water

3. Methods of analysis (Cd)

*Method accreditation: Yes / No

Sample amount used for analysis: .....

*Sample treatment: No treatment / Dilution / Wet digestion / Microwave-assisted digestion
Others (please specify): .....

*Analytical Instrument(s): ICP-MS / ICP-OES / Flame AAS / Others (please specify): .....

* Quantification technique: External calibration / Internal calibration / Standard additions / IDMS /
Others (please specify): .....

Calibration standard: .....

Internal standard (if any): .....

Matrix CRM or QC sample (if any): .....

Recovery of matrix CRM / QC (%): .....

*Correction for recovery: Yes / No

Additional information / Sources of MU / Any abnormal observations and problems encountered during analysis:

.....

.....

.....

* Please delete as appropriate

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Trace Elements in Natural Water

4. Methods of analysis (Sb)

*Method accreditation: Yes / No

Sample amount used for analysis: .....

*Sample treatment: No treatment / Dilution / Wet digestion / Microwave-assisted digestion
Others (please specify): .....

*Analytical Instrument(s): ICP-MS / ICP-OES / Flame AAS / Others (please specify): .....

* Quantification technique: External calibration / Internal calibration / Standard additions / IDMS /
Others (please specify): .....

Calibration standard: .....

Internal standard (if any): .....

Matrix CRM or QC sample (if any): .....

Recovery of matrix CRM / QC (%): .....

*Correction for recovery: Yes / No

Additional information / Sources of MU / Any abnormal observations and problems encountered during analysis:

.....

.....

.....

* Please delete as appropriate

Asia-Pacific Economic Cooperation

APEC Proficiency Testing Scheme

Trace Elements in Natural Water

5. Methods of analysis (Pb)

*Method accreditation: Yes / No

Sample amount used for analysis: .....

*Sample treatment: No treatment / Dilution / Wet digestion / Microwave-assisted digestion
Others (please specify): .....

*Analytical Instrument(s): ICP-MS / ICP-OES / Flame AAS / Others (please specify): .....

* Quantification technique: External calibration / Internal calibration / Standard additions / IDMS /
Others (please specify): .....

Calibration standard: .....

Internal standard (if any): .....

Matrix CRM or QC sample (if any): .....

Recovery of matrix CRM / QC (%): .....

*Correction for recovery: Yes / No

Additional information / Sources of MU / Any abnormal observations and problems encountered during analysis:

.....

.....

.....

* Please delete as appropriate

ANNEX H

PROGRAMME BOOKLET FOR POST-MEASUREMENT WORKSHOP

Workshop Objectives

The Workshop brings together participants from metrology institutes, accreditation bodies, regulatory bodies and water testing laboratories in public & private entities. It provides a platform forin stitutes & laboratories to share their experiences in undertaking measurements in the study onTr ace Elements (antimony, arsenic, cadmium and lead) in Natural Water. Discussions will focus onre sults from measurements undertaken in parallel through an Inter-American Metrology System (SIM)Su pplementary Comparison (SIM.QM-S12), an Asia Pacific Metrology Programme (APMP) Pilot Study(APM P.QM-P41) and an Asia-Pacific Economic Cooperation (APEC) proficiency test (PT).

The Workshop also provides the opportunity to identify capability and knowledge gaps, and propose action plans for future strategies to improve laboratory practices, measurement capabilities, and understanding of relevant international standards.

PROGRAMME OVERVIEW

6 MARCH 2023 / 1:00 to 9:00 UTC / In-Person & Virtual

Commencement times in different locations: Mexico City - 5 March, 19:00; Ottawa/Washington DC - 5 March, 20:00; Santiago - 5 March, 22:00); Wellington - 6 March, 14:00; Sydney - 6 March, 12:00; Lae - 6 March, 11:00; Seoul - 6 March, 10:00; Beijing/Manila/Ulaanbaatar - 6 March, 09:00; Bangkok/Jakarta - 6 March, 08:00; New Delhi - 6 March, 06:30.

Implementing Quality Management System for Water Testing

A.M.

TOPIC: IMPORTANCE OF QUALITY INFRASTRUCTURE IN ENSURING WATER QUALITY

Chairs: Prof. Zoltan Mester & Prof. Ping He

01:00 - Welcome address by Dr Tang Lin Teo & Dr Angela Samuel

01:10 - Introduction to the workshop by Prof. Zoltan Mester

01:20 - Overview of the workshop by Dr Angela Samuel

01:30 - Regulatory Framework to Support Water Quality by Ms Stéphanie McFadyen

02:00 - Standards, Conformity and Accreditation by Ms Anita Rani

02:30 - Break

03:00 - Role of Certified Reference Materials in Ensuring Metrological Traceability by Prof. Ping He

- *Updates on the Status of ISO/IEC 17025, ISO 17034 & ISO/IEC 17043* by Prof. Ping He

03:30 - Q&A

04:00 - Break

P.M.

TOPIC: ACCURACY-BASED PROFICIENCY TESTING (PT) PROGRAMMES AND APEC WATER PT PROGRAMME OUTCOMES

Chairs: Prof. Liandi Ma & Dr Della Sin

Panel: Mr Jeffrey Merrick, Dr Kelvin Tse, Dr Chao Jingbo, Dr Benny Tong, Dr Kim Sook Heun (KRISS)

05:00 - Roles of Accuracy-Based PT Programmes in Supporting Quality Infrastructure by Dr Sook Heun Kim

05:30 - Reference Value Assignments for APEC Water PT Samples by Mr Jeffrey Merrick

06:15 - Rigorous Measurement Uncertainty Evaluation Approaches by Dr Benny Tong

06:45 - Break

07:15 - Performance Evaluation and Results from APEC Water PT Programme by Dr Kelvin Tse

08:00 - Q&A and panel discussion

08:30 - Review and closing of Day 1 activities by Chairs

09:00 - End

PROGRAMME OVERVIEW

7 MARCH 2023 / 1:00 to 9:00 UTC / In-Person & Virtual

Commencement times in different locations: Mexico City - 6 March, 19:00; Ottawa/Washington DC - 6 March, 20:00; Santiago - 6 March, 22:00); Wellington - 7 March, 14:00; Sydney - 7 March, 12:00; Lae - 7 March, 11:00; Seoul - 7 March, 10:00; Beijing/Manila/Ulaanbaatar - 7 March, 09:00; Bangkok/Jakarta - 7 March, 08:00; New Delhi - 7 March, 06:30.

APEC Water PT Programme - Lessons Learned

Chair: Ms Anita Rani

Panel: Prof. Zoltan Mester, Mr Jeffrey Merrick, Dr Kelvin Tse, Dr Chao Jingbo & Dr Fransiska Dewi

01:00 to 08:00 - Presentations on methodology used, approach to measurement uncertainty evaluation & method validation and measurement challenges by invited participants of the SIM SC and APEC PT Programme [Breaks: 02:30 to 03:00 / 04:00 to 05:00 / 06:45 to 07:15]

08:00 - Summary and discussion on major concerns reported by participants by Dr Fransiska Dewi

08:15 - Panel discussion

08:45 - Review and closing of Day 2 activities by Chair

09:00 - End

PROGRAMME OVERVIEW

8 MARCH 2023 / 1:00 to 9:00 UTC / In-Person Only*

International Women's Day Celebration

Chair: Dr Tang Lin Teo

01:00 - Women in STEM presentations by Ms Chantal Guay, Dr Angela Samuel, Ms Anita Rani and Dr Shima Hashim

Producing Reference Material For Laboratory Use

Chair: Prof. Zoltan Mester

02:00 - Overview of ISO 17034 for Production of In-House QC Samples and/or CRMs by Prof. Ping He and Ms Anita Rani [Break: 02:30 to 03:00]

03:30 - Q&A

04:00 - Break

Chairs: Prof. Liandi Ma & Dr Tang Lin Teo

05:00 - Production of In-House QC Samples and/or CRM – Sharing of Experience from National Research Council, Canada by Prof. Zoltan Mester

05:30 - Production of In-House QC Samples and/or CRM – Sharing of Experience from Korea Research Institute of Standards & Science by Dr Sook Heun Kim

06:00 - Statistical Tools for Certification of CRM (ISO Guide 35) by Dr Benny Tong

06:30 - Break

07:00 - Group discussion - Case studies on production of in-house QC or RM Facilitated by Dr Sook Heun Kim, Dr Fransiska Dewi, Dr Chao Jingbo, Dr Benny Tong, Dr Tang Lin Teo, Mr Jeffrey Merrick, Ms Anita Rani & Dr Samuel Cheung

08:00 - Q&A

08:30 - Review and closing of Day 3 activities by Chairs

09:00 - End

*Except for Invited Experts

PROGRAMME OVERVIEW

9 MARCH 2023 / 1:00 to 9:00 UTC / In-Person Only*

Establishing Sustainable Quality Infrastructure for Current and Future Testing Needs

Chairs: Prof. Zoltan Mester, Dr Angela Samuel & Dr Della Sin

01:00 - Round table / Group discussion
Facilitated by Prof. Zoltan Mester, Dr Shima Hashim, Prof. Liandi Ma, Dr Benny Tong, Dr Tang Lin Teo, Mr Jeffrey Merrick, Ms Anita Rani & Dr Samuel Cheung

Topics to be covered:

- *Regulatory Framework and Quality Infrastructure in Participants' Economies*
- *Developmental Status of the Metrology Institutes (Staff Competency & Retention, Existing Metrology Services, Accreditation Status, Funding Levels, etc.)*
- *Testing Parameters of Concern – Routine and Emerging*
- *Access to Instrumentation, Training, Expertise and Other Resources*
- *Availability of CRMs, Inter-Laboratory Comparisons or PT Programmes and Other Metrological Services*
- *Action Plans & Road Maps: New Measurement Capabilities, Testing or Metrological Services, New or Expanded Accreditation Scopes*
- *Capacity Building Needs*
- *Future Capability Building Activities*

[Breaks: 02:30 to 03:00 / 04:00 to 05:00]

05:00 - Presentations by invited participants from APMP DEC

06:00 - Break

06:30 - Reports and presentations on discussion outcomes by participants

08:30 - Conclusion by Dr Tang Lin Teo

09:00 - End

*Except for Invited Experts

Invited Experts/Speakers

Ms Anita Rani, Joint Director, National Accreditation Board for Testing & Calibration Laboratories (NABL), India

Ms Anita Rani has a postgraduate degree in Agricultural Chemicals from the University of Delhi, India. She has about 18 years' experience and has developed her expertise in areas related to pesticides testing, residues analysis, chemical weapons, and has handled all chromatographic & spectroscopic equipment. Ms Rani joined NABL in the year 2011 and is pivotal in the development of PT Provider accreditation programme in NABL. She is member in ISO/CASCO WG 57 working on the revision of ISO/IEC 17043 standard, ISO/TC 69, ISO/CASCO WG 56 & ISO TC 334. She is the Convenor of APAC communication WG. She is also an APAC evaluator for Testing (Chemical), PTP & RMP. Ms Rani is presently Joint Director. Leading PTP & RMP accreditation program, Assessor training program, Portal, PT based Schemes and QA in NABL.

Dr Sook Heun Kim, Principal Scientist, Korea Research Institute of Standards and Science (KRISS), Republic of Korea

Dr Sook Heun Kim obtained her Ph.D. degree in Chemical Engineering from Purdue University in 2007 and worked as a post-doctoral fellow at the university between 2007-2009. At present, she is the Principal Scientist at KRISS which she joined since 2009. Dr Kim possesses extensive experience and analytical skills. Her scientific focus is on the development of CRMs for elemental analysis and accurate-based PT programmes. Dr Kim is actively involved in several activities of the Asian Collaboration on Reference Materials (ACRM), key comparisons and pilot studies.

Dr Kelvin Tse Chun Wai, Chemist, Government Laboratory (GL), Hong Kong, China

Dr Kelvin Tse received his Ph.D. in Chemistry at The University of Hong Kong in 2017. Two years later, he joined the GL as a chemist, with his work focusing on metrology development related to inorganic analysis. He is one of GL's representatives at the Inorganic Analysis Working Group of the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM) of the International Bureau of Weights and Measures (BIPM). He has broad exposure covering production of reference materials, provision of proficiency testing schemes, participation and organization of international comparison studies.

Mr Jeffrey Merrick, Senior Inorganic Scientist, National Measurement Institute, Australia (NMIA)

Mr Jeffrey Merrick graduated with Honours from the University of Sydney in 2006. The following year he joined the NMIA. He is currently the Senior Inorganic Chemist with the Chemical Reference Values section of NMIA. He is primarily responsible for the delivery of high accuracy measurements for CRMs, PT schemes and international comparisons. His work focuses on the measurement of inorganic analytes using ICP-MS and carbon isotope ratios using IRMS.

Invited Experts/Speakers

Ms Chantal Guay, CEO, Standards Council of Canada, Canada

Ms Chantal Guay was appointed Chief Executive Officer of the Standards Council of Canada (SCC) in 2018. Prior to this role, Ms. Guay was SCC's Vice President, Standards and International Relations, where she was responsible for overseeing management of the Canadian standardization network. She also served as SCC's Vice President, Accreditation Services for 5 years, where she led the unit's transformation and established a new customer-centric business model. Ms. Guay holds a Bachelor in Geological Engineering from Université Laval. She has a Master's degree in Environmental Management from Université de Sherbrooke. Ms. Guay earned an Advanced Executive Certificate in General Management from the Queen's University School of Business in 2012. She received the ICD.D designation from the Institute of Corporate Directors in 2021 after completing the ICD-Rotman Directors Education Program.

Ms Stéphanie McFadyen, Scientist, Health Canada, Canada

Ms Stéphanie McFadyen is a scientist at Health Canada. She is the research manager of the Water Quality Program and has been working on water quality and human health issues for more than 25 years. Her focus is on understanding and dealing with the health risks from substances–bacteria, viruses, parasites, chemicals, and radionuclides– in drinking and recreational water. She works closely with experts to develop guidelines and advice that are used as the basis of water quality standards to protect the health of Canadians. Stéphanie holds a BSc from Trent University, ON, Canada and an MSc from Carleton University, ON, Canada.

Dr Benny Tong Meng Kiat, Senior Analytical Scientist, Health Sciences Authority, Singapore

Dr Benny Tong received his Ph.D. degree from Nanyang Technological University in 2014. He is currently a Senior Analytical Scientist in HSA's Chemical Metrology Laboratory. He first joined the Inorganic Chemistry Section in 2015 and later moved on to the Organic Chemistry Section in 2019. Dr Benny is well-versed in higher order techniques such as isotope dilution mass spectrometry and standard additions techniques. He is familiar in various instrumentation such as ICP-MS, GC/LC-MS, TGA and NMR. He has over 7 years' experience in providing statistical training to local and overseas laboratories' analysts. He also is involved in the international key comparison data evaluations.

Organising Committee

Dr Tang Lin Teo
Division Director, Chemical Metrology Division, Health Sciences Authority, Singapore | Project Coordinator, APEC SCSC 01 2021 | Chair, Workshop Organising Committee

Dr Angela Samuel
Director, International National Measurement Institute, Australia | Project Overseer, APEC SCSC 01 2021

Dr Della Sin
Chair, CCQM Key Comparison & CMC Quality Working Group | Project Coordinator, APEC SCSC 01 2021

Dr Shima Hashim
Division Director, Chemical Metrology Division, Department of Chemistry, Malaysia | Co-Project Overseer, APMP CWFG_01_FGI2021

Prof. Zoltan Mester
Team Leader, Inorganic Chemical Metrology, National Research Council, Canada | Liaison to SIM | Project Coordinator, APEC SCSC 01 2021

Prof. Ping He
Senior Manager, China National Accreditation Service for Conformity Assessment, PR China | Chair, APAC/TC1/PTSC | Convener, ISO/TC334/AG2

Prof. Liandi Ma
Director, Center for Reference Material Research and Management, National Institute of Metrology, PR China| Chair, APMP Focus Group on Clean Water | Project Coordinator, APEC SCSC 01 2021

Mr Paul McMullen
Sector Manager, Calibration, National Association of Testing Authorities, Australia | Convener, APAC/RMWG

Dr Samuel Tsz-chun Cheung
Chief Chemist, Other Scientific Services Group, Government Laboratory, Hong Kong, China

Dr Fransiska Dewi
Senior Analytical Scientist, Chemical Metrology Division, Health Sciences Authority, Singapore| Project Overseer, APMP CWFG_01_FGI2021 | Executive Secretary, Workshop Organising committee

Acknowledgments

The Organising Committee acknowledges

Colleagues from Government Laboratory (GL, Hong Kong, China), National Research Council (NRC, Canada) and National Measurement Institute (NMI, Australia) for co-organising SIM SC, APMP PS & APEC PT;

Colleagues from National Institute of Metrology (NIM, China) and Health Sciences Authority (HSA, Singapore) for providing the assigned values for the APEC PT together with GL (Hong Kong, China), NRC (Canada) and NMI (Australia);

APEC, APMP, SIM and Physikalisch-Technische Bundesanstalt (PTB, Germany) for providing financial support to this event;

APAC for contributing Experts for this event;

Department of Chemistry (KIMIA, Malaysia) for providing support as local host of this event;

HSA (Singapore) for hosting the virtual segment of this event; and

All invited Speakers/Experts who have taken time to share their knowledge with participants of this event, including their Organisations who have supported them in their undertaking.

ANNEX I

PRE-WORKSHOP SURVEY (FOR IN-PERSON AND VIRTUAL ATTENDEES)
POST-MEASUREMENT WORKSHOP

Pre-Workshop Survey (2023 Post-Measurement Workshop)

10 mins estimated time to complete

Participants' Details

1. Salutation

Select an option

2. First Name

3. Last Name

4. Gender

Select an option

5. Job Title

6. Institute / Laboratory / Company

7. Economy

8. Email

Laboratory's/Institute's/Company's Accreditation Status

9. Are the current services of your institute/laboratory/company in water testing accredited?

Select an option

10. Are you planning to seek accreditation or extend the accreditation scope of your water testing services?

Select an option

Participation in APEC PT and Interest in Other PT Programmes

11. Did your institute/laboratory participate in the APEC PT on "Trace Elements in Natural Water"?

No	Yes

12. What parameters do you wish to be covered in the next regional water PT programme? (optional)

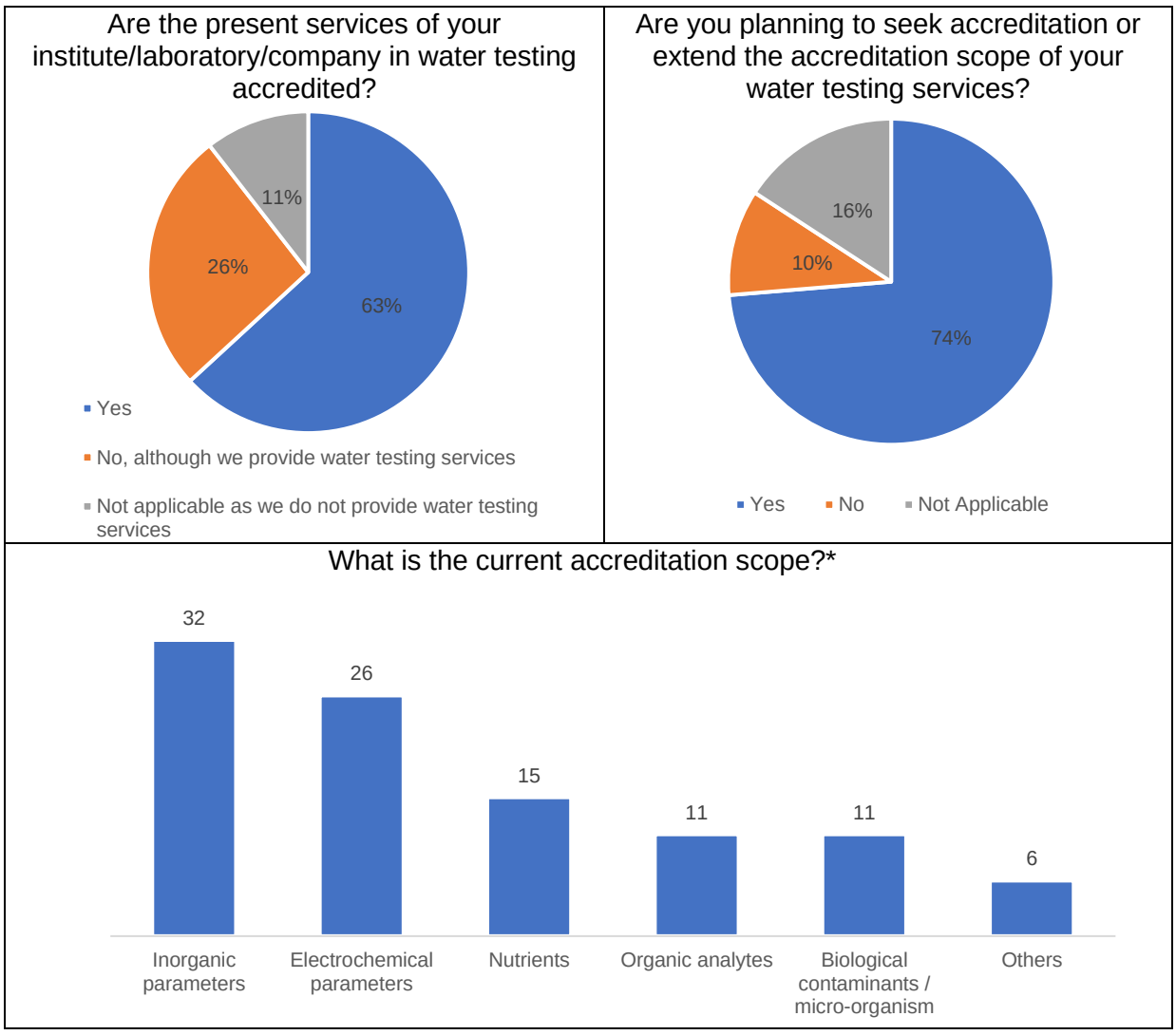
- [ ] Inorganic parameters (e.g. toxic elements)
- [ ] Nutrients (e.g. anions)

- [ ] Organic analytes (e.g. pesticides, polycyclic aromatic hydrocarbons)
- [ ] Electrochemical parameters (e.g. pH, conductivity)
- [ ] Biological contaminants / micro-organism
- [ ] Others

13. Do you have any question that you would like to be addressed at the Post-Measurement Workshop in March 2023?

Submit now

Based on the survey, 63.2% (36 out of 57) of the respondents are accredited for water testing and 26.3% (15 out of 57) are not, though they are providing services in the area. Another 10.5% (6 out of 57) are not providing water testing services. The top three accreditation scopes for water testing covered inorganic parameters, electrochemical parameters and nutrients. These were consistent with the scopes that the respondents indicated they wish to cover in the next regional water PT programme. The majority, or 73.7% (42 out of 57) of the respondents shared that they plan to seek accreditation or extend their accreditation scopes to cover more areas of water testing. Inorganic parameters were identified as the top parameters in which respondents intend to apply or extend their accreditation scopes. See Figure I1a for the survey results.



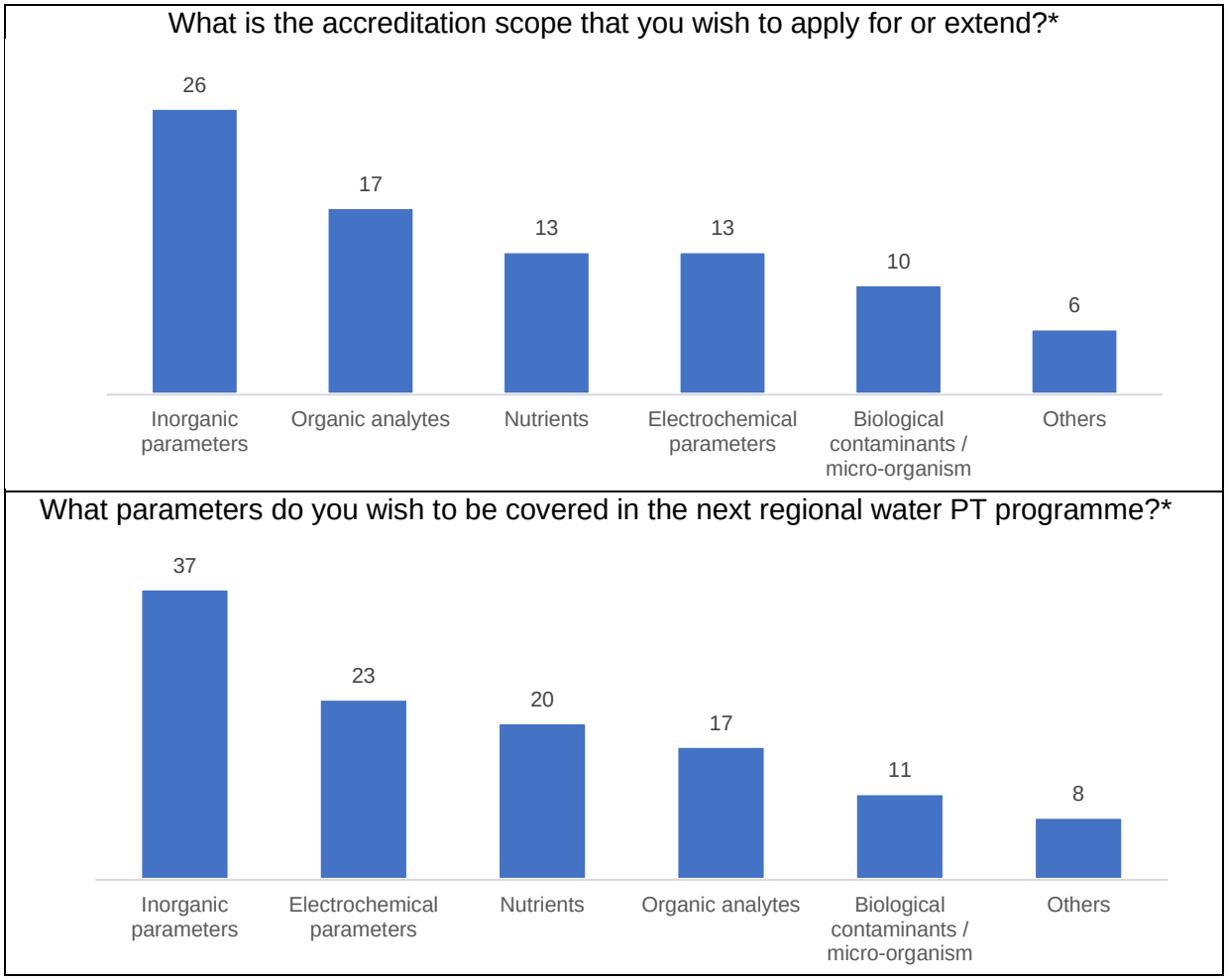


Figure I1a: Charts showing the pre-workshop survey questions (both in-person and online) and responses from 57 individuals. *Denotes multiple selection was allowed.

A total of 64.9% (37 out of 57) of the respondents participated in the APEC PT. Also, 88.2% (25 out of 29) stated that their participation in the APEC PT had provided evidence to support their institute/laboratory's accreditation status. The majority of the respondents that participated in the APEC PT were either very satisfied or somewhat satisfied with the organisation of the APEC PT. The detailed feedback can be found in Section 5.6. See Figure I1b for the survey results.

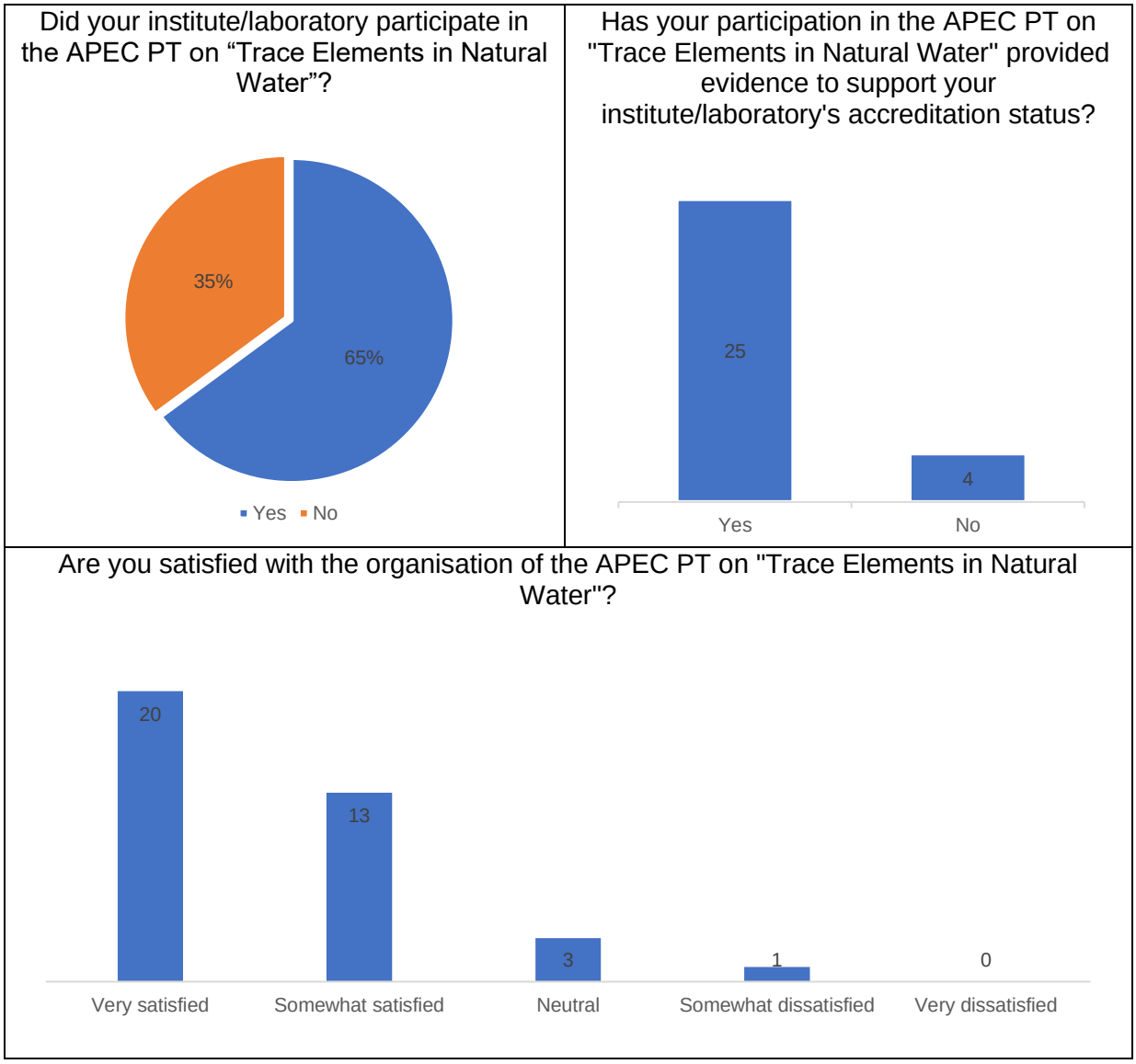


Figure I1b: (Continued) Charts showing the pre-workshop survey questions (both in-person and online) and responses from 57 individuals.

ANNEX J

PRE-WORKSHOP SURVEY (FOR IN-PERSON ATTENDEES) POST-MEASUREMENT WORKSHOP

Pre-workshop Questionnaire for Post-Measurement Workshop (Onsite Participants)

30 mins estimated time to complete

Participants' Particular

1. Economy

2. Name of Company / Institute

3. Nature of Business

- ◯ Government agency
- ◯ Private Laboratory
- ◯ Others

4. Salutation of Participant

Select an option

5. Name of Participant

6. Gender

Select an option

7. Job Title

8. Email Address

Water Regulatory Framework and Quality Infrastructure in Your Economy

9. Which aspect(s) of water regulations and/or guidelines and/or their enforcements do you think could be further enhanced to ensure the water quality and safety in your economy?
You may select more than 1 option.

- [ ] Nothing, they are adequate
- [ ] Inclusion of more (potentially) hazardous compounds
- [ ] More stringent safety limits
- [ ] More frequent sampling
- [ ] More rigorous testing
- [ ] Not sure
- [ ] Others

10. **Which aspect(s) of the standard and conformance network in your region do you think could be further enhanced to support the water testing needs in your economy and/or the region?**
You may select more than 1 option.

- [ ] Nothing, they are adequate
- [ ] Wider scope of accreditations
- [ ] Better guidelines on how to attain and/or maintain accreditations
- [ ] More relevant training
- [ ] More stringent requirements
- [ ] More lenient requirements
- [ ] Assessors with expertise in specific areas
- [ ] Closer network between accreditation bodies and testing laboratories
- [ ] Not sure
- [ ] Others

About Your Institute

11. **Please describe the level of competency of technical staff pertaining to measurement of parameters relevant to water quality based on the current needs of your institute and/or your economy.**

- ◯ Very competent
- ◯ Competent
- ◯ Somewhat competent

- ○ Not competent in some areas
- ○ Not sure

12. **Please describe the level of technical staff retention within your organisation.**

- ○ Very high (almost all staff stay for a long period of time)
- ○ High (most staff stay for a long period of time)
- ○ Medium (some staff left, but overall measurement capabilities are not affected)
- ○ Low (a significant number of staff left, which affected the organisation measurement capabilities)
- ○ Not sure

13. **Please describe the current services offered by your institute.**

You may select more than 1 option.

- ☐ Testing services or value assignments
- ☐ Certified reference materials (CRMs)
- ☐ Proficiency testing (PT) programmes
- ☐ Training
- ☐ Not applicable

14. **If you have selected one or more of the first three choices in the previous question, please select the areas/scopes covered.**

You may select more than 1 option.

- ☐ Inorganic analysis
- ☐ Organic analysis
- ☐ Electrochemical analysis
- ☐ Biological analysis
- ☐ Analysis of emerging contaminant
- ☐ Not applicable

- [ ] Others

15. **If your institute offers training, please select the areas/scopes covered.**
You may select more than 1 option.

- [ ] Technical skills (e.g. isotope dilution mass spectrometry, standard addition)
- [ ] International Standards (e.g. ISO/IEC 17025, ISO 17034 or ISO/IEC 17043)
- [ ] Method validation
- [ ] Measurement uncertainty
- [ ] Not applicable
- [ ] Others

16. **What are the challenges encountered in delivering these services?**
You may select more than 1 option.

- [ ] Lack of human resources
- [ ] Limited measurement capabilities and access to training
- [ ] Limited access to instrumentation or inadequate facilities
- [ ] Limited network with other stakeholders
- [ ] Insufficient funding support
- [ ] Not applicable
- [ ] Others

17. **Are the current needs or demands for metrology services in your economy fulfilled?**

- ◯ Fulfilled
- ◯ Somewhat fulfilled
- ◯ Not fulfilled in some areas
- ◯ Not sure
- ◯ Others

18. **Please describe the accreditation status in respect of water measurement of your institute.**

- ◯ Accredited
- ◯ Non-accredited
- ◯ Others

19. **Is your institute intending to go for a new accreditation or to expand the scope of your accreditation in the next 5 years?**

- ◯ New accreditation
- ◯ Expansion of scope
- ◯ Both new accreditation and expansion of scope
- ◯ No

20. **Please describe the funding levels received by your institute.**

- ◯ More than sufficient
- ◯ Generally sufficient
- ◯ Almost sufficient

- ○ Insufficient
- ○ Prefer not to disclose
- ○ Others

Testing Parameters of Concern

21. Please describe the routine and emerging testing parameters of concern to water quality in your economy, taking into account the current and upcoming regulations and past outbreaks or threats locally or regionally, etc.
You may select more than 1 option.

- ☐ Inorganic analysis
- ☐ Organic analysis
- ☐ Electrochemical analysis
- ☐ Biological analysis
- ☐ Analysis of emerging contaminants
- ☐ Not sure
- ☐ Others

22. Please elaborate more on the routine and emerging testing parameters of concern to water quality in your economy. (optional)

23. How would you rate your institute's current capabilities and capacities in addressing the routine and emerging testing parameters of concern to water quality in your economy?

- ◯ 4 - Able to address all testing parameters of concern (routine and emerging)
- ◯ 3 - Able to address all routine testing parameters of concern
- ◯ 2 - Able to address some of the routine testing parameters of concern
- ◯ 1 - Able to address small portion of the routine testing parameters of concern
- ◯ Not sure

Access to Instrumentation, Training, Expertise and Other Resources

24. **How would you rate the access that the water testing laboratories in your economy have to instrumentation required for the measurement of the testing parameters of concern to water quality in your economy?**

- ◯ 4 - Most laboratories have access to instrumentation required for measurement of most of the testing parameters of concern (routine and emerging)
- ◯ 3 - Most laboratories have access to instrumentation required for measurement of most of the routine testing parameters of concern
- ◯ 2 - Some laboratories have access to instrumentation required for measurement of most of the routine testing parameters of concern
- ◯ 1 - A few laboratories have access to instrumentation required for measurement of most of the routine testing parameters of concern
- ◯ Not sure

25. **How would you rate the access that the water testing laboratories in your economy have to training and expertise required for the measurement of the testing parameters of concern to water quality in your economy?**

- ◯ 4 - Most laboratories have access to training and expertise required for measurement of most of the testing parameters of concern (routine and emerging)
- ◯ 3 - Most laboratories have access to training and expertise required for measurement of most of the routine testing parameters of concern

- ◯ 2 - Some laboratories have access to training and expertise required for measurement of most of the routine testing parameters of concern
- ◯ 1 - A few laboratories have access to training and expertise required for measurement of most of the routine testing parameters of concern
- ◯ Not sure

26. **Is there any other resource(s) required for the measurement of the testing parameters of concern to water quality in your economy?**
You may select more than 1 option.

- ☐ Adequate laboratory setup
- ☐ Access to chemicals (e.g. standards, CRMs, reagents)
- ☐ Access to PT programmes
- ☐ Networks with other laboratories within the economy or region
- ☐ Networks with other stakeholders
- ☐ Not sure
- ☐ Others

Availability of CRMs, Inter-Laboratory Comparisons or PT Programmes and Other Metrological Services

27. **Are CRMs / inter-laboratory comparisons or PT programmes / value assignment services relevant to water quality available in your economy?**

- ◯ All available
- ◯ Mostly available
- ◯ Some available

- ○ Mostly unavailable
- ○ Not sure
- ○ Others

Action Plans: New Measurement Capabilities, Testing or Metrological Services

28. **Please describe new measurement capabilities that your institute and water testing laboratories in your economy are planning to develop (further).**
You may select more than 1 option.

- ☐ Inorganic analysis
- ☐ Organic analysis
- ☐ Electrochemical analysis
- ☐ Biological analysis
- ☐ Analysis of emerging contaminants
- ☐ Not applicable
- ☐ Others

29. **Please describe new services that your institute and water testing laboratories in your economy are planning to offer.**
You may select more than 1 option.

- ☐ New value assignment or testing services
- ☐ New or expanded lists of CRMs
- ☐ New or expanded scopes of PT programmes
- ☐ Not applicable

- [ ] Others

30. **What can be done for or by your institute and these laboratories to be equipped to develop such capabilities and services?**
You may select more than 1 option.

- [ ] Not applicable, no new capability or service to be developed or offered
- [ ] Not applicable, already fully equipped
- [ ] Better instrumentation or laboratory facilities
- [ ] Training (workshop, attachment)
- [ ] Access to CRMs
- [ ] Participation in PT programmes or inter-laboratory comparisons
- [ ] Not sure
- [ ] Others

Capacity Building Needs

31. **What are the most urgent capacity building needs of your institute and water testing laboratories in your economy?**

- ( ) More skilled technical staff
- ( ) More advanced instrumentation and laboratory facilities
- ( ) Funding support
- ( ) None
- ( ) Others

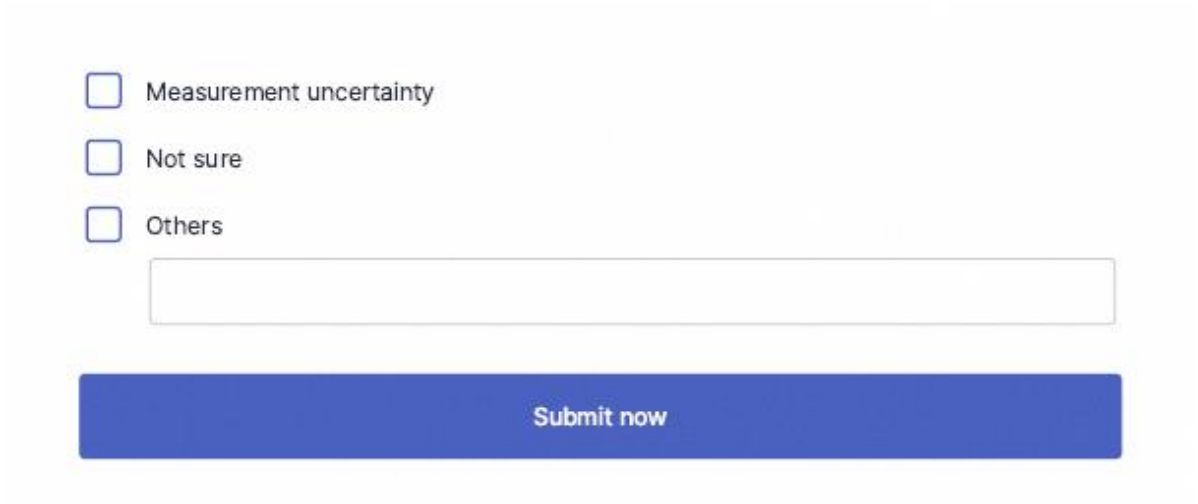
Recommendations for Future (1-5 years) Capability Building Activities

32. **What are the topics or scopes of future capability building activities that would be relevant to your institute?**
You may select more than 1 option.

- [ ] Technical skills (e.g. isotope dilution mass spectrometry, standard addition)
- [ ] Testing and/or calibration requirements (in accordance with ISO/IEC 17025)
- [ ] CRM production (in accordance with ISO 17034)
- [ ] PT organisation (in accordance with ISO/IEC 17043)
- [ ] Method validation
- [ ] Measurement uncertainty
- [ ] Not sure
- [ ] Others

33. **What are the topics or scopes of future capability building activities that would be relevant to your economy?**
You may select more than 1 option.

- [ ] Technical skills (e.g. isotope dilution mass spectrometry, standard addition)
- [ ] Testing and/or calibration requirements (in accordance with ISO/IEC 17025)
- [ ] CRM production (in accordance with ISO 17034)
- [ ] PT organisation (in accordance with ISO/IEC 17043)
- [ ] Method validation


Measurement uncertainty
Not sure
Others
Submit now

ANNEX K

PHOTOGRAPHS TAKEN DURING POST-MEASUREMENT WORKSHOP

Figure K1: Post-Measurement workshop attendees (onsite and online).

Figure K2: Live dialogue session with three successful women in STEM on International Women's Day: Dr Shima Hashim, Ms Anita Rani (from left to right) and Dr Angela Samuel (online). The session was chaired by Dr Teo Tang Lin (on the right).

Figure K3: Workshop attendees in small-group discussion focus on the topic of establishing sustainable quality infrastructure for current and future testing needs.

ANNEX L

SURVEY FOR WOMEN IN STEM (POST-MEASUREMENT WORKSHOP)

Survey on Women in STEM

10 mins estimated time to complete

Instructions

This survey is designed to gather inputs from the Workshop participants, in alignment with APEC's commitment to increasing women and girls' participation in STEM.

Participants' Details

1. Salutation

Select an option

2. First Name

3. Last Name

4. Gender

Select an option

5. Job Title

6. Institute / Laboratory / Company

7. Economy

8. Email

Level of Female Representation and Involvement

9. Please indicate the percentage of women in your division or laboratory.

- ◯ 0 - 10%
- ◯ 10 - 30%
- ◯ 30 - 50%
- ◯ 50 - 80%
- ◯ 80 - 100%

10. Please indicate the percentage of key managerial positions held by women in your division or laboratory.

- ◯ 0 - 10%
- ◯ 10 - 30%
- ◯ 30 - 50%
- ◯ 50 - 80%
- ◯ 80 - 100%

11. Among the staff members from your division or laboratory that were involved in the APEC PT on "Trace Elements in Natural Water" or parallel run comparison, please indicate the percentage of women.

- ◯ 0 - 10%
- ◯ 10 - 30%
- ◯ 30 - 50%
- ◯ 50 - 80%
- ◯ 80 - 100%
- ◯ Not applicable (did not participate in the APEC PT or parallel run comparison)

Opportunities and Challenges

12. Have you observed or experienced any barrier for women to gain equal opportunities to advance their careers in STEM?

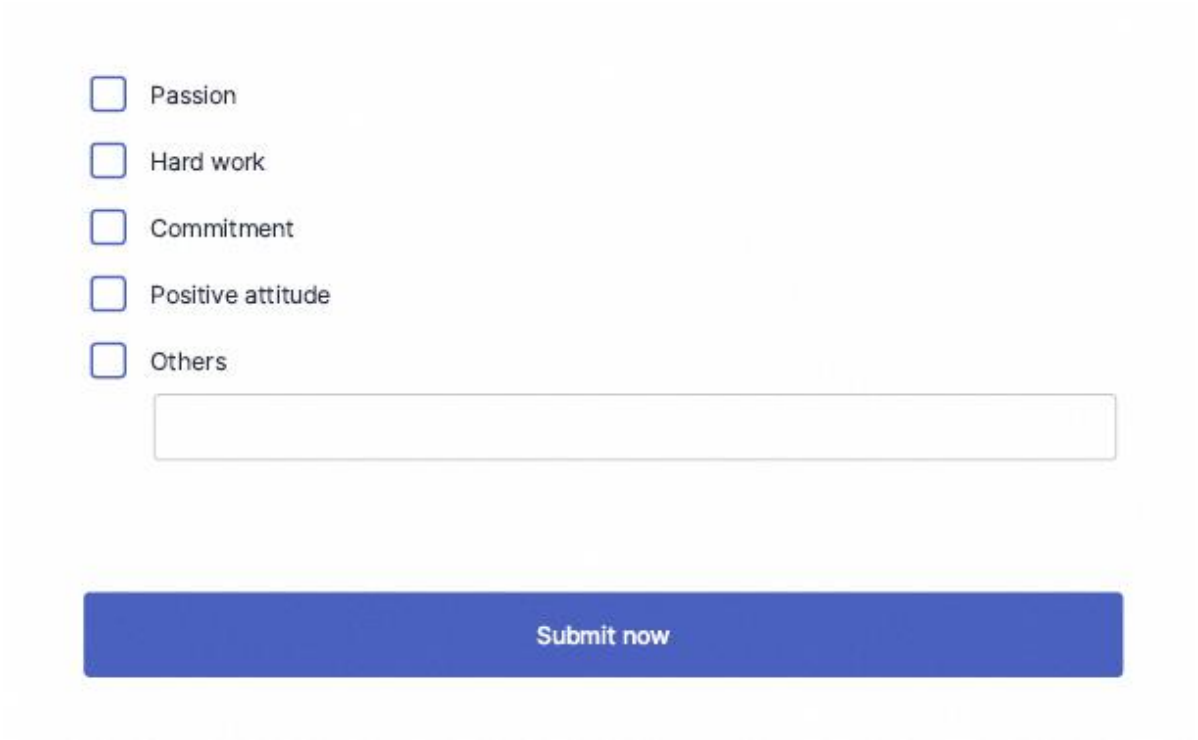
No	Yes

13. Does your institute / laboratory have any policy / programme to ensure equal opportunities for women?

No	Yes

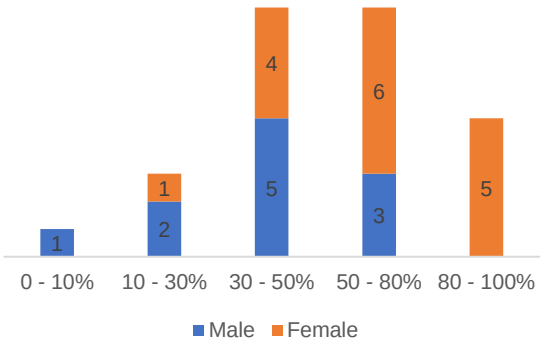
14. What are the key success factors that have inspired you the most from the International Women's Day Sharing?
Please select not more than 3 answers.

- ☐ Teamwork
- ☐ Support from colleagues
- ☐ Continuous learning
- ☐ Versatility

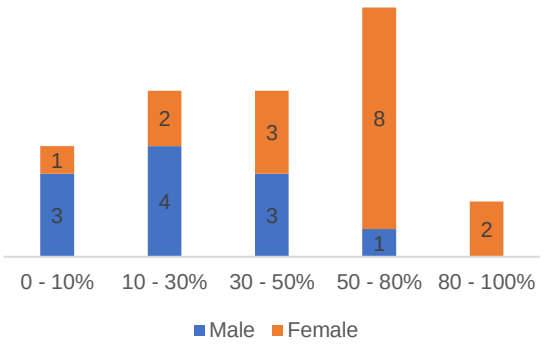

Passion
Hard work
Commitment
Positive attitude
Others
Submit now

Based on the gender-aggregated survey outcomes, most of the respondents indicated that about 30 – 80% of staff in their division or laboratory are women. Approximately 33.3% indicated that the percentage of key managerial positions held by women in their division or laboratory was between 50 – 80%. There is no particular trend to highlight regarding the percentage of women involved in the APEC Water PT or APMP.QM-P41 and SIM.QM-S12. However, almost all respondent expected more women to be involved in similar projects in future and most of them recognised that there were benefits from having more women involved in such projects. See Figure L1a for the survey results.

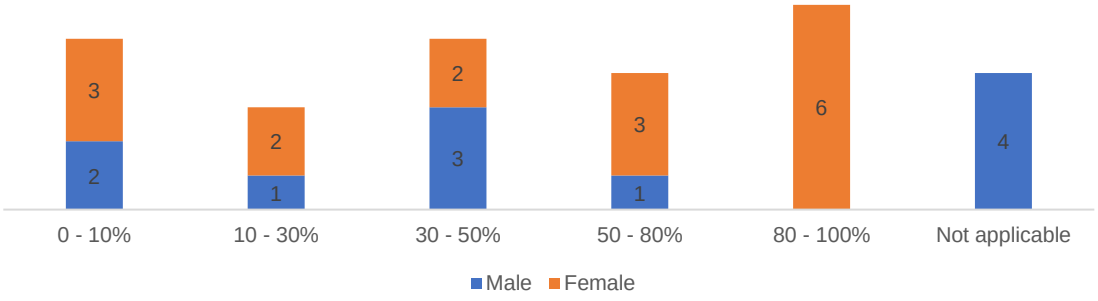
Please indicate the percentage of women in your division or laboratory.



Please indicate the percentage of key managerial positions held by women in your division or laboratory.



Among the staff members from your division or laboratory that were involved in the APEC PT on Trace Elements in Natural Water or parallel run comparison, please indicate the percentage of women.



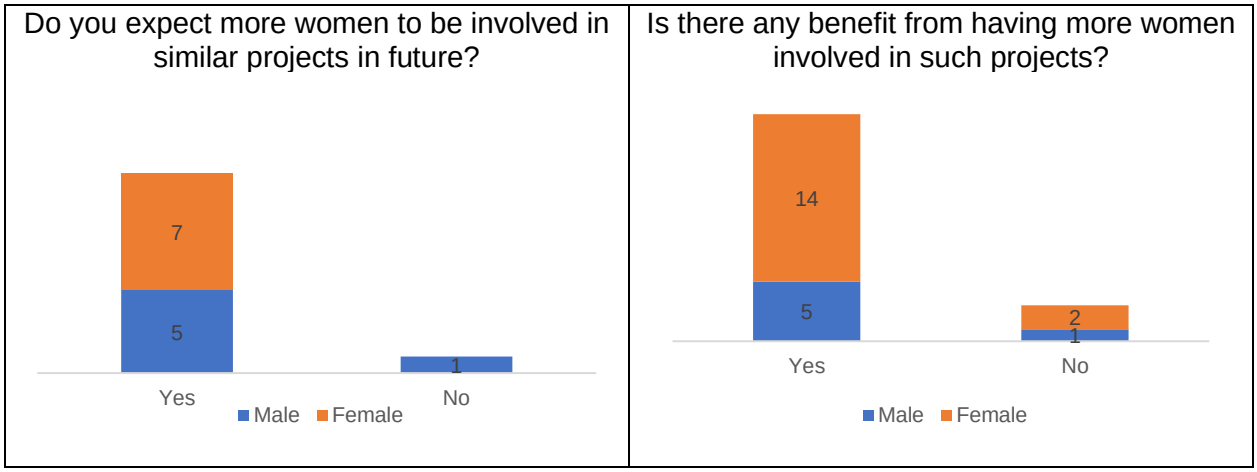
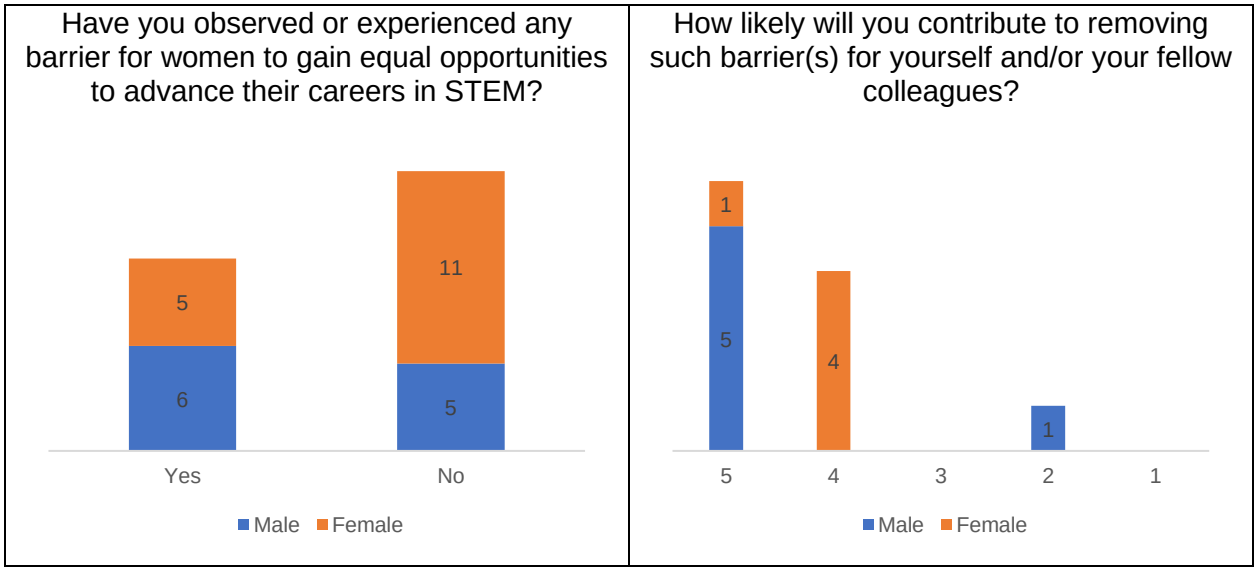


Figure L1a: Charts showing the women in STEM survey questions and responses from 27 individuals. Data reflecting male and female respondents are in coloured in blue and orange, respectively.

Based on the survey, 59.3% (16 out of 27) of the respondents indicated that they did not observe or experience any barrier for women to gain equal opportunities to advance their careers in STEM. Almost all respondents that observed or experienced this barrier stated that it was either very likely or likely for them to contribute to removing such barrier(s) for themselves and/or their fellow colleagues through ensuring equal opportunities regardless of gender and striving to provide work-life balance or flexibility at work. However, 66.7% of the respondents stated that their institutes/laboratories did not have any policy / programme to ensure equal opportunities for women See Figure L1b for the survey results.



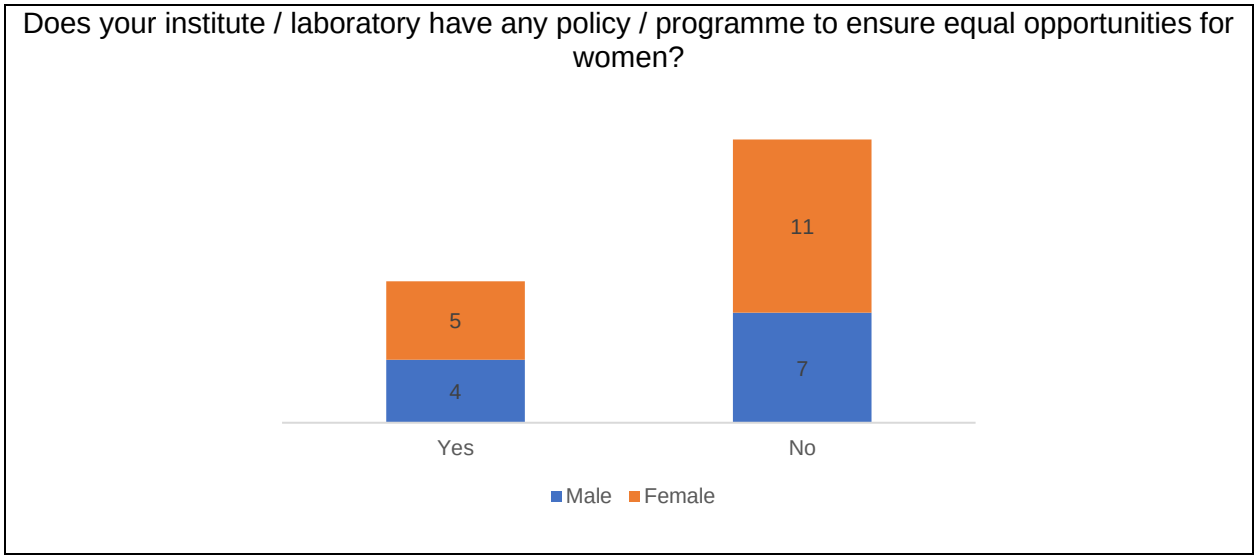


Figure L1b: (Continued) Charts showing the women in STEM survey questions and responses from 27 individuals. Data reflecting male and female respondents are in coloured in blue and orange, respectively.

ANNEX M

POST-WORKSHOP SURVEY (POST-MEASUREMENT WORKSHOP)

Post-Workshop Survey (2023 Post-Measurement Workshop)

15 mins estimated time to complete

Participants' Details

1. Salutation

Select an option

2. First Name

3. Last Name

4. Gender

Select an option

5. Job Title

6. Institute / Laboratory / Company

7. Economy

8. Email

Workshop Attendance

9. I attended the workshop

Select an option

Feedback Regarding the Topics of the Workshop

10. How relevant were the topics covered in this workshop to you and your economy?
5 = "Very relevant"
4 = "Mostly relevant"
3 = "Somewhat relevant"
2 = "Slightly relevant"
1 = "Not relevant"

☆ ☆ ☆ ☆ ☆

11. Please rate your level of knowledge and/or technical know-how in the topics prior to attending the workshop.
5 = "Very good"
4 = "Good"
3 = "Well"
2 = "Fair"
1 = "Poor"

☆ ☆ ☆ ☆ ☆

12. Please rate your level of knowledge and/or technical know-how in the topics after

attending the workshop.
5 = "Very good"
4 = "Good"
3 = "Well"
2 = "Fair"
1 = "Poor"

13. How likely will you apply the knowledge learnt from the workshop to your work?
5 = "Very likely"
4 = "Likely"
3 = "Maybe"
2 = "Unlikely"
1 = "Very unlikely"

14. What new skills and knowledge did you gain from this Workshop?
You may select more than 1 option.

- [ ] Regional and international quality infrastructures
- [ ] International Standards (ISO/IEC 17025, ISO 17034 and ISO/IEC 17043)
- [ ] Organisation of accuracy-based proficiency testing programmes
- [ ] Production of certified reference materials
- [ ] Inorganic analysis techniques and how to overcome measurement challenges
- [ ] Measurement uncertainty evaluation
- [ ] Regional and international testing capabilities
- [ ] Regional and international capacity building and knowledge transfer needs
- [ ] Others

15. After attending this Workshop, which skill(s) do you wish to pick up in order to increase the impacts of your works?

Please select not more than 3 answers.

- [ ] Technical skills
- [ ] Quantitative reasoning
- [ ] Design thinking
- [ ] Critical thinking
- [ ] Problem scoping
- [ ] Decision-making
- [ ] Communication
- [ ] Active listening
- [ ] Persuasion
- [ ] Teamwork
- [ ] Cultural engagement
- [ ] Leadership
- [ ] Others

Feedback Regarding the Organisation of the Workshop

16. The objectives of the workshop were clearly defined.
3 = "Strongly agree"
2 = "Agree"
1 = "Disagree"

☆ ☆ ☆

17. The workshop has achieved its intended objectives.
3 = "Strongly agree"
2 = "Agree"
1 = "Disagree"

18. The topics covered in the workshop were relevant to my work.
3 = "Strongly agree"
2 = "Agree"
1 = "Disagree"

19. The content was well organised and easy to follow.
3 = "Strongly agree"
2 = "Agree"
1 = "Disagree"

20. Gender issues were sufficiently address during implementation.
3 = "Strongly agree"
2 = "Agree"
1 = "Disagree"

21. The speakers were well prepared and knowledgeable about the topics that they have covered.
3 = "Strongly agree"
2 = "Agree"
1 = "Disagree"

22. The materials presented in the workshop were sufficient given the timeframe allocated.
3 = "Strongly agree"
2 = "Agree"
1 = "Disagree"

23. The time allocated for each topic was reasonable and the programme was well paced.
3 = "Strongly agree"
2 = "Agree"
1 = "Disagree"

24. The platform used for the workshop was user-friendly, it allowed me to interact with the speakers and panelists, and I did not encounter technical issues with using it.
3 = "Strongly agree"
2 = "Agree"
1 = "Disagree"

25. What do you consider as the Workshop's biggest achievements?

26. Do you have any feedback or comment with regards to the Workshop? (optional)

Submit now

Based on the survey, all respondents found the Workshop topics to be mostly or very relevant to themselves or their economies (average score of 4.7 out of 5.0). All respondents either strongly agree or agree that the topics were relevant to their work (average score of 2.8 out of 3.0). The majority or 71.7% (43 out of 60) of them rated their level of knowledge/technical know-how before the Workshop as very good or good on the topics, this rose to 93.3% (56 out of 60) after attending the Workshop. The average score of the level of knowledge/technical know-how were 4.0 and 4.5 out of 5.0 before and after the Workshop, respectively. See Figure M1a.

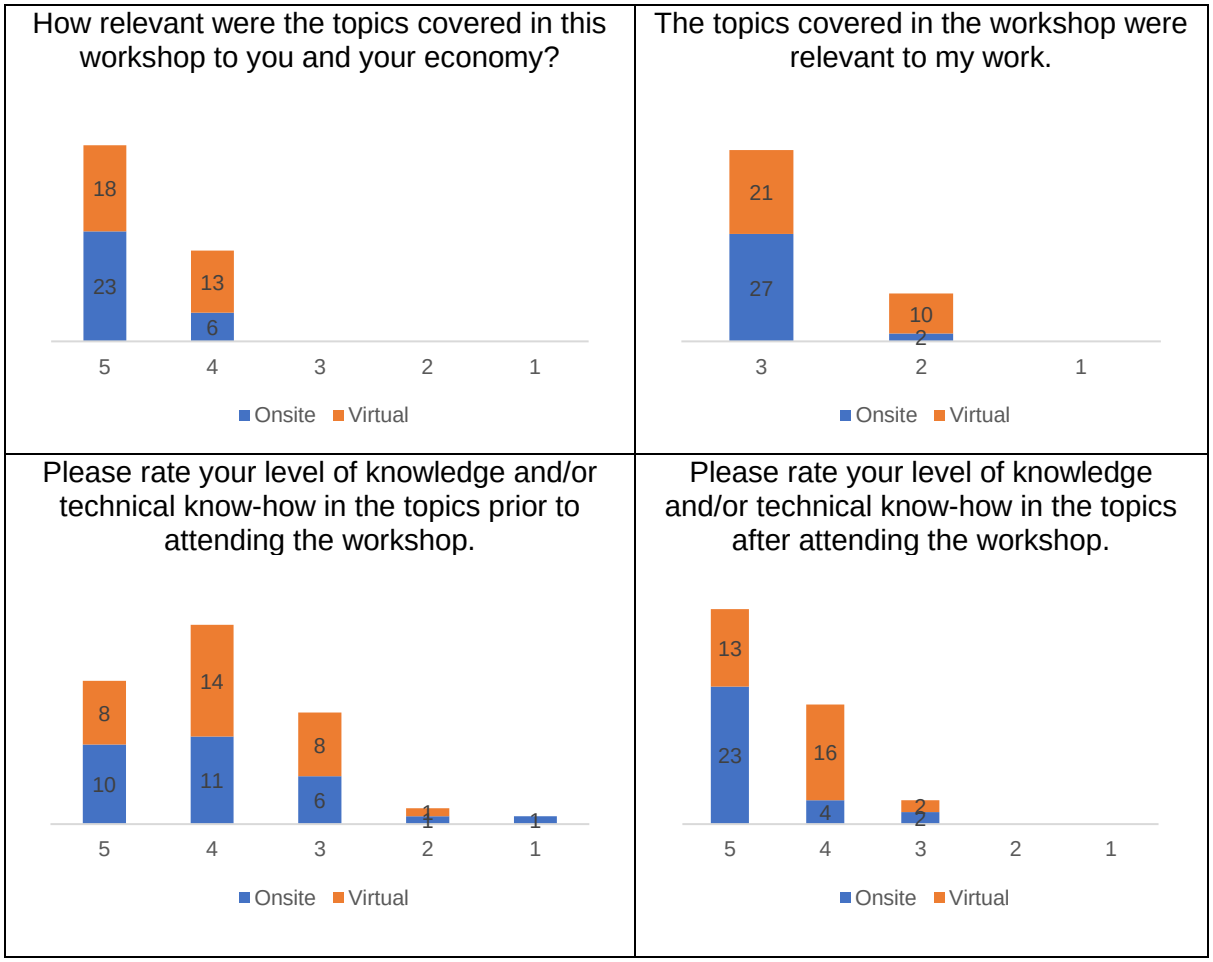


Figure M1a: Charts showing the post-workshop survey questions and responses from 60 individuals. Data reflecting respondents from onsite and virtual attendees are coloured in blue and orange, respectively.

Over 96.7% (and up to 100.0%) of the attendees agreed or strongly agreed that the objectives of the workshop were clearly defined and achieved; the content was well organised and easy to follow; gender issues were sufficiently addressed; the speakers had provided sufficient materials and they were well prepared and knowledgeable; the workshop was well-paced; and the selected platform was user-friendly and allowed interactions with the speakers. The average scores for these indicators were between 2.7 to 2.9 out of 3.0. See Figure M1b.

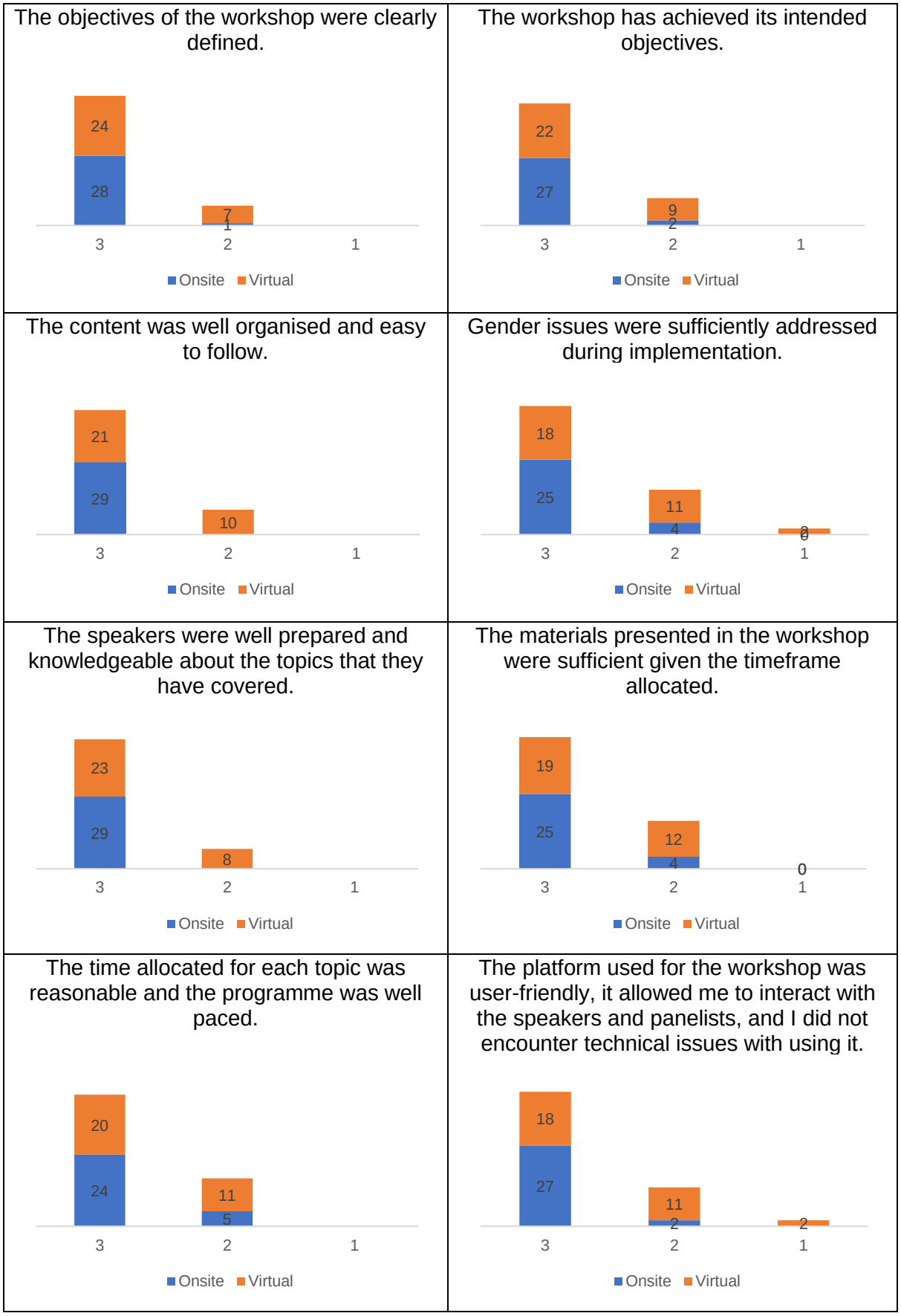
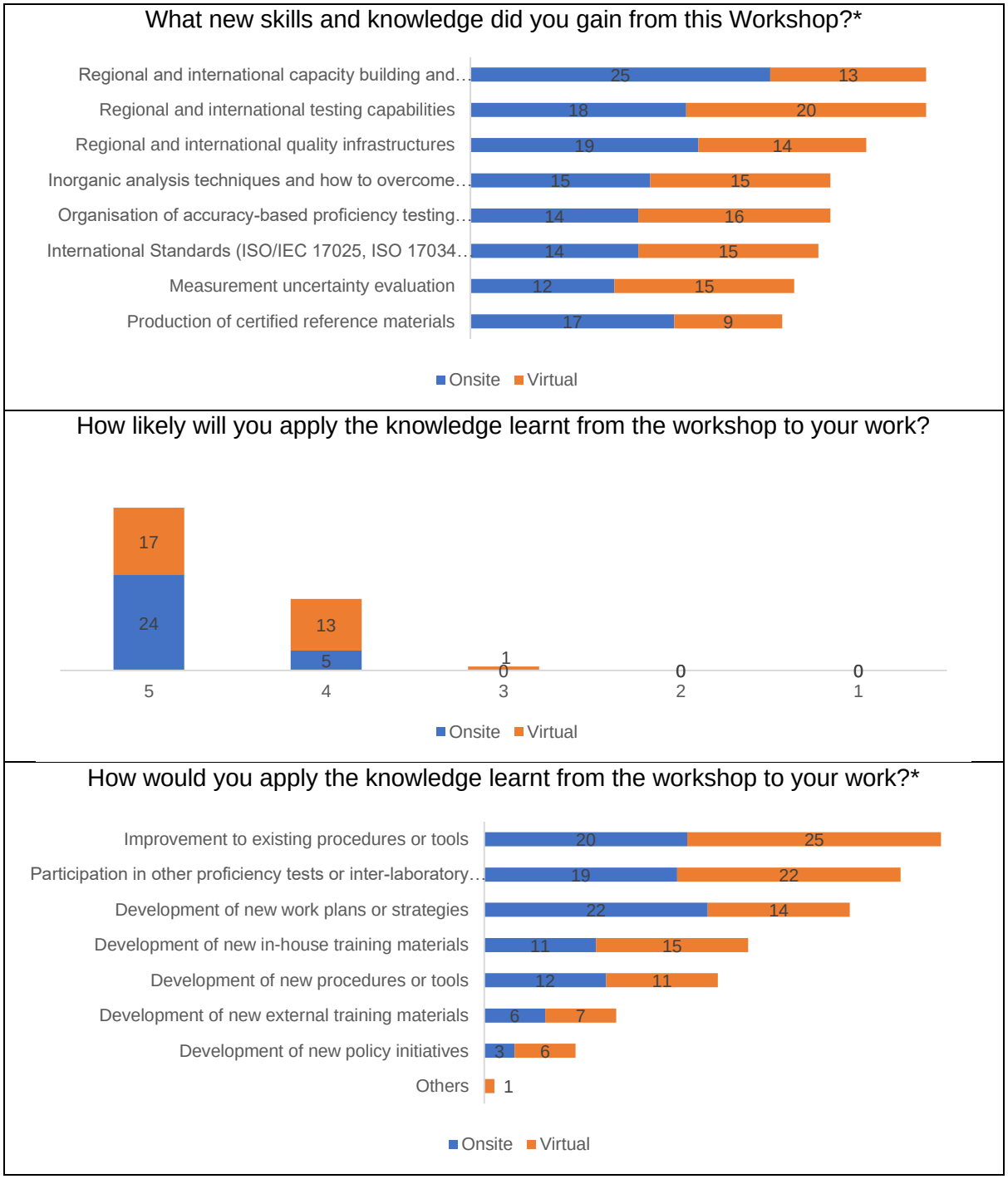


Figure M1b: (Continued) Charts showing the post-workshop survey questions and responses from 60 individuals. Data reflecting respondents from onsite and virtual attendees are coloured in blue and orange, respectively.

It was encouraging to learn that the respondents gained several new skills and knowledge from this Workshop and intended to apply the knowledge acquired from the workshop to improving existing procedures or tools in their work; participation in other PTs or inter-laboratory comparisons; development of new work plans or strategies; etc. More than half of the respondents also wished to pick up other technical skills in order to increase the impact of their works. There were several soft skills, such as decision making, design thinking and problem scoping that were identified as important to increase the impact of their works. See Figure M1c.



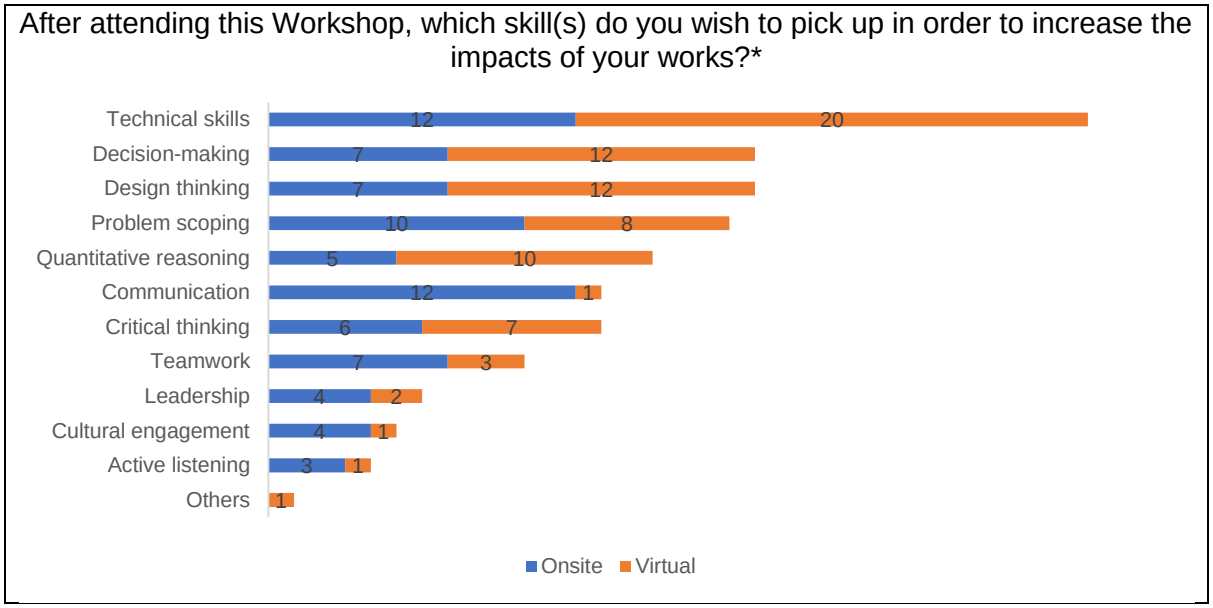


Figure M1c: (Continued) Charts showing the post-workshop survey questions and responses from 60 individuals. Data reflecting respondents from onsite and virtual attendees are coloured in blue and orange, respectively. *Denotes multiple selection was allowed.