

Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM)

CCQM Working Group on Inorganic Analysis (IAWG) Strategy for 2021-2030

Version 1 (December 2020)

1. EXECUTIVE SUMMARY

The CCQM Inorganic Analysis Working Group (IAWG), in cooperation with regional metrology organizations (RMOs), provides a global framework to support and promote SI traceability in inorganic chemical analysis, ensuring that measurement services provided by member institutes are as comparable as possible and of adequate quality for the intended purposes. IAWG activities promote improvements and developments in the science and practice of inorganic chemical metrology worldwide. This is especially important for relatively new technologies, for which suitable traceability infrastructures may still be lacking. The workspace of the IAWG is broad, including quantitative measurements of the elements, cations and anions, inorganic compounds, and organometallic compounds in matrices which include pure materials, calibration solutions and complex samples, such as those used for matrix reference materials. Virtually every sector of modern science and technology is ultimately dependent upon the IAWG's activities.

The IAWG will continue in 2021-2030 the excellent work that has characterized its history since its establishment in 1997. CIPM key comparisons with parallel pilot studies will continue to be performed to improve and demonstrate global comparability of inorganic chemical measurement capabilities across the entire IAWG measurement space. The vastness of this measurement space necessitates a busy key comparison schedule, and much work in recent years has been directed toward reducing the number of required studies. Considerable efforts will be devoted toward further refinements of the IAWG core capability approach to enable calibration and measurement capability (CMC) claims to be underpinned with maximum efficiency, especially regarding so-called broad-scope CMC claims, where a single claim covers multiple analytes and/or multiple sample matrices.

The IAWG plans to focus significantly on further metrological developments in several areas that have been identified for growth by the working group. These areas include measurements of nanoparticles; element-based measurements of biomolecules; elemental speciation measurements; and direct measurements of solids, possibly with imaging. While none of these areas are completely new to the modern world, they all require improvements in measurement methods and SI-traceability infrastructures, making them ripe for IAWG involvement. To meet the needs, the IAWG plans to hold workshops and perform standalone pilot studies. When measurement capabilities are developed adequately, key comparisons can be performed, enabling the first CIPM demonstrations of comparability in measurement capabilities among participating institutes.

Along with these activities, the IAWG has decided to continue its steady work in evaluating and improving SI-traceability for inorganic chemical metrology generally. Traceability schemes for inorganic chemical analysis are usually adequate for the measurement tasks at hand, except in some emerging areas, such as those just listed. Nevertheless, it is prudent for the IAWG to seek continually to understand better the current limitations of SI-traceability and to make improvements to accepted practices. This effort will help prepare today's inorganic chemical metrologist for the measurement problems of the future.

Finally, it should be mentioned that the IAWG will focus efforts on the 'grand challenges' currently being adopted by the CIPM. These include (1) climate change and the environment, (2) health and the life sciences, (3) food safety, (4) energy, and (5) advanced manufacturing. The activities mentioned above fit well within these challenge areas. Moreover, the IAWG will always be looking for additional opportunities to have impact in these areas and, in fact, in any important areas not foreseen in this document.

2. SCIENTIFIC, ECONOMIC AND SOCIAL CHALLENGES

Inorganic chemical metrology is as old as analytical chemistry itself. Consequently, it is as well developed as any of the subdisciplines of analytical chemistry. Even so, today's inorganic chemical metrologist continually faces new and daunting challenges, including needs for ever improving analytical sensitivity, limits of detection, robustness, uncertainty estimations, metrological traceability, trueness, and productivity. Additionally, as modern science and technology advance, new inorganic measurement problems emerge and require the development of new methods, instrumentation, and metrological reference systems. The importance of such scientific issues is realized and magnified by the negative impact that failure to meet these challenges has on human and environmental health, economics, and trade. The current wellbeing and future advancement of the modern world literally depend upon the widespread availability of quality inorganic chemical metrology and the broad recognition of inorganic analysis results around the world.

Inorganic chemical measurements are required by nearly every industrial and technological sector. For example, petroleum producers must meet tight environmental regulations regarding the contents of sulfur and mercury in their products. Manufacturers of metal alloys and cements must carefully control the elemental composition of their products to ensure that buildings and bridges meet engineering specifications. Food producers need to be certain that the products they are providing to the public do not contain unsafe levels of toxic elements, like mercury, lead, cadmium, and arsenic. Medical professionals require accurate quantification of various elements and inorganic species in body fluids. Environmental regulators are concerned with ensuring that the natural environment is not overly contaminated by human activity, necessitating measurements of many elements in the periodic table and inorganic species in soils, sediments, and natural water. Such a list of examples could extend for many pages.

Over the twenty-four year history of the IAWG, much of its work has been devoted to demonstrating and improving the comparability of inorganic chemical measurements among the world's national metrology institutes (NMIs) and designated institutes (DIs) that are charged

with establishing and maintaining the measurement systems for their respective nations. In this way, a global measurement system is being built to serve all the sectors of science, technology, industry, and commerce. The IAWG conducts key comparisons (KCs) to evaluate the comparability of the measurement capabilities of its member institutes and to provide those institutes with support for calibration and measurement capability (CMC) claims. The IAWG also conducts pilot studies (PSs) in parallel to such KCs to enable institutes that are inexperienced with the measurements at hand to evaluate and improve their capabilities on a preliminary basis. The vastness of the footprint of the IAWG can be judged by reflecting on the scope of the work undertaken:

- A very wide range of analytes has been addressed, including approximately 60 elements and ten anions, isotope ratios and delta scale isotopic values, organo-metallic compounds (elemental speciation) and inorganic compounds or complexes. [Note: The isotope ratio work has been transferred to the CCQM Isotope Ratio Working Group (IRWG) that was formed in 2018.]
- It is necessary for the IAWG to support ten different CMC categories ranging from water and calibration solutions to biological fluids and advanced materials.
- At least ten different measurement techniques, ranging from classical chemistry to the most advanced instrumentation, are in regular use, often with several employed in the same comparison.

The gathering of numerous institutes in mutual participation in these comparisons naturally leads to each institute learning from the others. Shortcomings in measurement approaches are identified, best practices are transferred, and the overall comparability of measurement capabilities around the world improves. This is one of the main benefits provided through active participation in the work of the IAWG. Over the history of the IAWG, the level of measurement capability demonstrated by participants in the KCs and PSs has improved beyond all recognition. The initial work in the late 1990s essentially comprised measurement of simple calibration solutions under optimum conditions, and yet the claimed uncertainties and the equivalence among participants were relatively poor. Over the years, both indicators have improved dramatically, even as the required measurements have moved to ever lower analyte content levels in increasingly complex samples.

Metrological traceability to the SI is a key component of achieving comparability of measurement capability among the institutes. In approximately the past seven years, the IAWG has focused attention on evaluating the state of metrological traceability for inorganic chemical analysis. Ultimately, traceability to the SI for the analytical techniques used in IAWG measurements derives from carefully assayed high-purity materials. Therefore, the IAWG has undertaken a number of studies to assess the capability of its members to conduct purity assays, as well as to prepare calibration solutions from them. Notably, the most prevalent elemental impurities in many high-purity metals that are used as the basis for SI traceability are the nonmetallic elements, which are some of the most difficult elements in the periodic table to quantitate with good traceability to the SI. Therefore, the IAWG plans to continue this work.

IAWG Success Case #1 – Roadmap for purity determination

Problem: Metrological traceability to the SI for inorganic chemical measurement results ultimately traces to the assigned purity values of high-purity elements or inorganic compounds. The IAWG recognized a need to provide guidance to its members regarding fit-for-purpose practice in the evaluation of purity for such high-purity materials.

IAWG Activities: Since 2006, the IAWG has carried out several comparisons to evaluate, develop, and demonstrate comparability amongst its members regarding purity assessment capability. These include CCQM-P62 (Purity of nickel with respect to six defined metallic analytes), CCQM-P107 (Purity of zinc with respect to six defined metallic analytes), CCQM-K72/P107.1 (Purity of zinc with respect to six defined metallic analytes), and CCQM-P149 (Purity determination of zinc to be used as primary standard for zinc determination). The quality and comparability of the member institutes of the IAWG improved notably over the course of these studies.

Outcome: Given the lessons learned, the IAWG produced a guidance document on fit-for-purpose purity evaluations of high-purity metallic elements. Published in 2017, this roadmap is located on the IAWG web site at https://www.bipm.org/wg/CCQM/IAWG/Restricted/April_2017/CCQM-IAWG17-28.pdf



The benefits will extend to inorganic chemical analyses generally, wherever performed, as practitioners purchase and use either CRMs from IAWG members or CRMs from commercial producers with assigned values that are traceable to the SI through the CRMs from IAWG members.

The IAWG also conducts standalone PSs (i.e., without parallel KCs) as a means of developing metrology for new measurement problems, with the goals being to mature the measurement methods, establish reliable SI traceability, and reach a point of useful comparability of measurement capabilities among the institutes. The interactions among members serve as mutual learning exercises and generate collaborations that lead to advancements. Through these mechanisms, the IAWG drives progress in inorganic analytical chemistry, realizing benefits to society.

Identification of such new areas in which the IAWG should become involved has historically been made through a bottom up process. The IAWG member institutes, which are in touch with their stakeholders and their regional metrology organizations (RMOs), propose to the IAWG new standalone PSs for new areas of activity. Although this mechanism does not facilitate direct interactions of the IAWG itself with inorganic chemical analysts in the field, it has worked well to keep the IAWG's activity portfolio relevant to society. Nevertheless, the IAWG might benefit from fostering a greater connection with the ultimate beneficiaries of its work – the organizations and companies that use the measurement services of the IAWG member institutes. Given the measurement needs of these ultimate customers of the IAWG members, the IAWG plans to focus continuing efforts on:

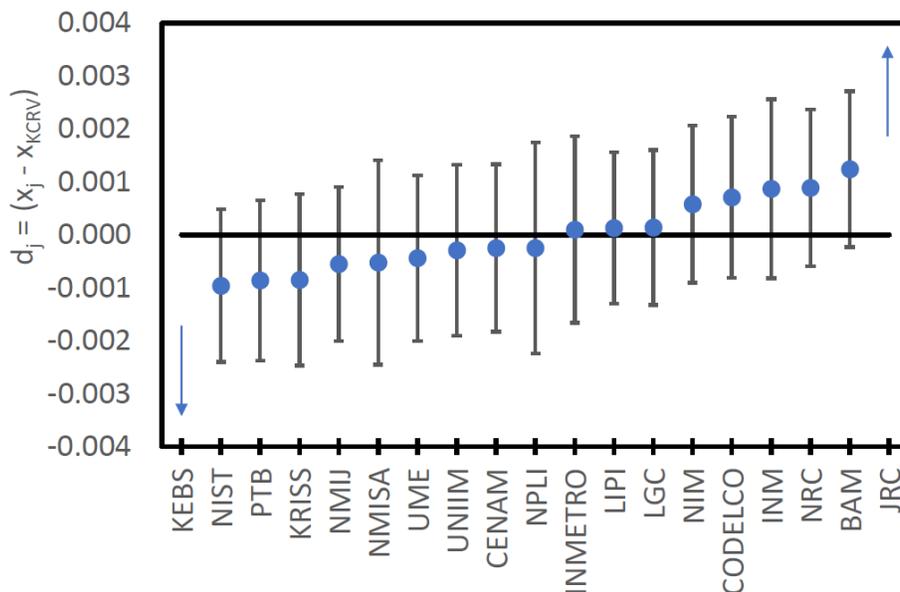
- **Nanoparticle metrology** – Nanoparticles are being used in a wide variety of technologies, from environmental cleanup [e.g., 1-3] to cancer treatment [e.g., 4-6] to chemical catalysis [e.g., 7-9]; many different sectors are affected. Even though use of nanoparticles in real world applications is not new, reliable, practical, and affordable methods of measurement for nanoparticles are sometimes unavailable to those who need them. Therefore, the IAWG continues to work in this field to enable the full promise of nanotechnology to be realized.
- **Element-based quantitation of biomolecules** – Many biomolecules contain within their chemical structures predictable amounts of elements that can be quantitated well using the techniques in which the IAWG is experienced [10]. For example, there is one phosphorus atom in each nucleotide in DNA, suggesting that measurement of phosphorus concentration can be used to measure nucleotide concentration, so long as other sources of phosphorus are adequately accounted [11, 12]. In this way, IAWG techniques can be used for the measurement of biomolecules, with the possibility of very good SI traceability, in a complementary way to the techniques employed by the more biology based CCQM WGs, notably the Protein Analysis Working Group (PAWG) and the Nucleic Acid Analysis Working Group (NAWG). The obvious stakeholders for this work are the medical, health, and biotechnology industries.
- **Elemental speciation** – The toxicity and bioavailability of chemical elements generally depend on the species in which they are found. For instance, while mercury itself is known to be toxic to human health, methylmercury is of far greater concern than inorganic mercury, because it is absorbed into the body much more readily. Elemental speciation metrology is required by many stakeholders, especially those in the food, medical, and environmental sectors. The IAWG has been working on the topic of elemental speciation metrology for 20 y, with the first pilot study registered in 2001 [CCQM-P18 (Tributyltin in sediment)]. Nevertheless, measurement methods and the metrological reference systems to underpin them are still not as well developed as needed by the stakeholders. It is prudent for the IAWG to continue working in this field.

IAWG Success Case #2 – CCQM-K143/P181 (Copper calibration solutions)

Problem: Nearly all inorganic chemical measurements made by IAWG member institutes are calibrated using standard solutions. A longstanding need within the CCQM has been an objective demonstration of the equivalence of calibration solutions prepared by the IAWG institutes to underpin their measurement services.

IAWG Activities: CCQM-K143/P181 (Comparison of copper calibration solutions prepared by NMIs and DIs) was conducted to demonstrate the equivalence of the capabilities of the IAWG members to prepare calibration solutions. Copper was selected as an exemplary element. CCQM-K143/P181 was a model 2 comparison, in which institutes prepared copper standard solutions and sent them to the pilot laboratory for side-by-side evaluation.

Outcome: As shown in the plot, the copper standard solutions prepared by the institutes agreed very well, demonstrating equivalent capabilities for the calibration of IAWG measurements.



The IAWG also has plans to engage in one new effort in response to the needs of stakeholders:

- **Small sample metrology and chemical imaging** – Certain sectors of science, technology, industry, and commerce are concerned with measurements of very small samples, with or without imaging, particularly in the solid state. Examples include electronics, energy, forensics, and medicine. The ability to perform measurements on very small samples is also important to many academic pursuits that may ultimately lead to economic benefits.

Consequently, the IAWG has identified small sample metrology, with the possibility of chemical imaging, as a new growth area for the future. The first pilot study, planned as a laser ablation ICP-MS study, is tentatively planned to begin in 2023. Because several other measurement techniques may also be applied, this is another technical area for which collaboration with other CCQM WGs is likely.

Several ‘grand challenges’ in metrology are currently being adopted by the CIPM. The purpose of this adoption is to stimulate metrological developments for the good of the global community in technical areas that are deemed especially pressing at the present time. These ‘grand challenges’ include (1) climate change and the environment, (2) health and the life sciences, (3) food safety, (4) energy, and (5) advanced manufacturing. The specific activities described above obviously fit well with these challenge areas. Moreover, the IAWG will be continually looking for additional opportunities for making impacts in these areas, and, in fact, any important areas not now foreseen, over the period covered by this document.

It is useful to conclude this section by highlighting some key technical advancements that have resulted from the IAWG’s work over its entire history:

- Reaching broad agreement among institutes around the world on the estimation of measurement uncertainties for complex inorganic chemical analyses as well as achieving ever smaller uncertainties for delivery of routine services.
- Systematically investigating factors influencing measurement reliability to achieve effective validation of high-level methods and rigorous propagation of the uncertainties associated with their results.
- Establishing ID-ICP-MS as the reference method of choice for a wide range of measurement applications and adopting well-validated procedures. The original aim was to develop a primary ratio method for metrology but the practical benefits of the technique for provision of reliable reference values far outweigh that goal.
- Collaboration on species-specific IDMS methodology for the application of hyphenated mass spectrometry techniques to speciation of organo-metallic or inorganic analytes, compared with the simpler post-column isotope dilution used by many expert academic groups.
- Developing the underlying principles of high accuracy NAA so that it could be considered as a potential primary method.
- Undertaking a structured investigation of purity assessment approaches for elemental calibrants and developing a “roadmap” setting out practical guidance for such assessments for applications ranging from primary calibrants to fit-for-purpose matrix sample analysis.

- Investigating the practical and economic aspects of establishing full SI traceability to replace the arbitrary scales (“Delta Values”) which are widely used for key applications of isotope ratio measurements.

3. VISION AND MISSION

Vision and mission statements for the CCQM

CCQM’s Vision: A world in which all chemical and biological measurements are made at the required level of accuracy to meet the needs of society.

CCQM’s Mission: To advance global comparability of chemical and biological measurement standards and capabilities, enabling member states and associates to make measurements with confidence.

4. STRATEGY

A description of the aims of the CCQM IAWG strategy in line with the CCQM vision and strategy

The strategic aims of the IAWG for the period covered by this document are the same as those for the CCQM itself, though focused on inorganic chemical metrology:

To contribute to the resolution of global challenges such as climate change and environmental monitoring, energy supply, food safety, healthcare including infectious disease pandemics, by identifying and prioritizing critical measurement issues and developing studies to compare relevant measurement methods and standards.

To promote the uptake of metrologically traceable inorganic chemical measurements through workshops and roundtable discussions with key stakeholder organizations, to facilitate interaction, liaison and cooperative agreements, and receive stakeholder advice on priorities to feed into the IAWG work program.

To progress the state of the art of inorganic chemical measurement science by investigating new and evolving technologies, measurement methods, and standards and coordinating programs to assess them.

To improve efficiency and efficacy of the global system of comparisons for inorganic chemical measurement standards conducted by the IAWG by continuing the development of strategies for a manageable number of comparisons to cover core capabilities.

To continue the evolution of CMCs to meet stakeholders’ needs, incorporating the use of broad CMC claims where applicable to cover a broader range of services and considering options to present these in a way that meets stakeholders’ needs and encourages greater engagement with the CMC database.

To support the development of capabilities at NMIs and DIs with emerging activities by promoting a close working relationship with RMOs, including mentoring and support for NMIs and DIs preparing to coordinate comparisons for the first time and promoting knowledge transfer activities, including workshops, as well as secondments to other NMIs, DIs and the BIPM.

To maintain organizational vitality, regularly review and, if required, update the IAWG structure for it to be able to undertake its mission and best respond to the evolution of global measurement needs by prioritizing where new areas or issues should be addressed within the structure and evolving working group remits as required.

5. ACTIVITIES TO SUPPORT THE STRATEGY

5.1. PROGRESSING METROLOGY SCIENCE

One of the enduring goals of the IAWG is to stimulate developments in inorganic measurement science to meet the evolving metrological needs of society.

- **Metrological traceability to the SI** – Nothing is more fundamental to inorganic chemical metrology than establishing traceability to the SI. Even though SI-traceability in inorganic chemical metrology is adequate for current applications, it can and should be improved to prepare for ever more stringent metrological requirements as modern society continues to develop.

As stated earlier, SI-traceability for inorganic chemical metrology ultimately depends upon high-purity materials that have been assayed for their purity. The assayed high-purity materials take the form of the elements themselves or compounds of the elements. Reliable purity assays can be quite challenging. Nowhere is this more apparent than in determinations of nonmetallic impurities in high-purity metals. Good measurement methods for nonmetallic impurities are not always available, and the comparability of capabilities among institutes is somewhat lacking. Therefore, the IAWG plans to focus attention on this problem. Discussions are already underway for a standalone PS to evaluate and advance the state of the science regarding determinations of several nonmetallic elements in high-purity metals. This planned PS follows several IAWG comparisons and studies over the years concerned with calibration materials. However, only one dealt specifically with comparing measurement results for metallic and nonmetallic impurities in a high-purity metal. CCQM-P149 (Estimation of impurities for the overall purity evaluation of zinc) reported comparability of measurement results among the participating institutes for hydrogen, nitrogen, carbon, and oxygen, among other elements. The level of comparability is acceptable, so long as the high-purity metal is truly of good purity; nevertheless, it can be improved.

Other problems of interest for purity assays include the most appropriate treatment of nondetectable elements, suitable ways to account for impurity

heterogeneity, and the obvious need for asymmetric uncertainty intervals. The IAWG may choose to focus attention on one or more of these issues, as well. Eventually, this work might lead to an update of the existing IAWG guidance document titled “Roadmap for the purity determination of pure metallic elements” (IAWG17-28, https://www.bipm.org/wg/CCQM/IAWG/Allowed/April_2017/CCQM-IAWG17-28.pdf).

Several relatively new technical areas in which the IAWG plans to be involved were introduced earlier. Specific details about the foreseeable plans for each are provided:

- **Nanoparticle metrology** – As stated earlier, reliable, practical, and affordable measurement methods for nanoparticles are often unavailable. Some IAWG member institutes are developing a relatively new technique, single particle (sp)ICP-MS [13, 14], as an alternative to traditional techniques like electron microscopy, dynamic light scattering, and small angle X-ray scattering. The technique can be used to measure the mean size, size distribution, and number concentration of a population of metal-containing nanoparticles suspended in a liquid. The unique combination of extremely rapid analysis and trueness makes spICP-MS a practical alternative, but the metrological infrastructure needed for its full application in the real world is inadequately developed.

The IAWG began discussing the metrological needs for nanoparticle science in earnest at a workshop, titled “Techniques for measurement of nanoparticle number concentration in colloidal suspension,” held during the April 2017 IAWG meeting. The first IAWG study in this area is CCQM-P194 (Number concentration of colloidal nanoparticles in liquid suspension), registered in 2017, and with the final report expected to be published sometime in 2021. It is noteworthy that several Surface Analysis Working Group (SAWG) members participated in CCQM-P194 using their more traditional measurement techniques. Nanoparticle metrology would seem to fit naturally in the purview of the SAWG, but spICP-MS naturally belongs in the IAWG. Therefore, there is an opportunity for continuing collaboration between the SAWG and the IAWG.

The next IAWG comparison for nanoparticles is CCQM-K166/P210 (Measurement of nanoparticle number concentration in liquid suspension). This has just been registered jointly in 2020 as a comparison within both the IAWG and the SAWG for the reasons just elucidated. The measurand will again be nanoparticle number concentration, but the precise nature of the sample(s) is still being discussed.

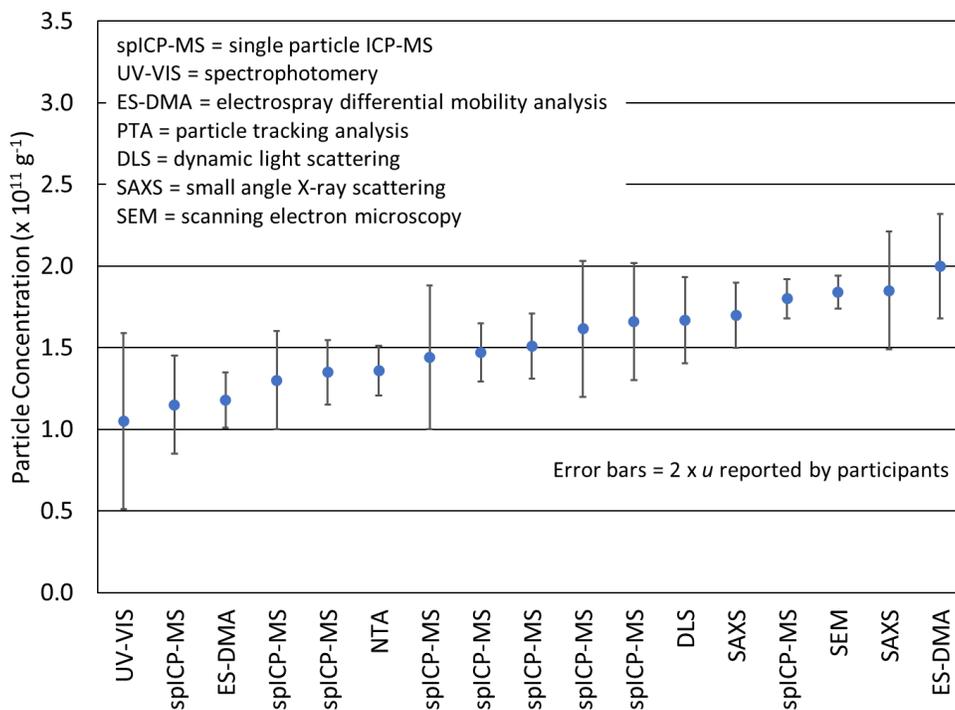
The new technique of spICP-MS can also be used to make very rapid measurements of nanoparticle size and size distribution of nanoparticles in suspension. During the timeframe covered by this strategy document, it is likely that the IAWG will organize workshops and studies for these measurands, as well, probably jointly with the SAWG. However, there are no specific plans yet.

IAWG Success Case #3 – Counting nanoparticles

Problem: Nanoparticles are important to many 21st century technology areas, including advanced manufacturing, healthcare, and food safety. Reliable and economical methods for measuring number concentrations of nanoparticles in liquid suspension are needed.

IAWG Activities: Several IAWG member institutes are developing single particle (sp)ICP-MS as an approach to perform measurements of particle size and size distribution and number concentration rapidly, economically, and with extremely good concentration sensitivity. In 2017 the IAWG undertook CCQM-P194 (Number concentration of colloidal nanoparticles in liquid suspension) to investigate the comparability of the results of spICP-MS measurements of number concentration with results of other techniques supplied by the Surface Analysis Working Group (SAWG).

Outcome: As shown in the plot, number concentration measurement by spICP-MS was found to agree well with several other techniques, many of which are much more established. The IAWG is now proceeding with CCQM K166/P210 (Nanoparticle number concentration in liquid suspension), registered jointly with the SAWG, to demonstrate comparability formally and to enable CMC claims.



- **Element-based quantitation of biomolecules** – Reliable measurements of biomolecules, such as proteins, peptides, nucleotides, DNA, and RNA are of great important to the medical and biotechnology fields. Therefore, the IAWG plans to place emphasis on such measurements over the coming years. Already, CCQM-

P156 (Element-based quantification and purity analysis of a dNMP standard solution) was registered in 2013 and completed, with the final report published in late 2016 (see https://www.bipm.org/wg/CCQM/IAWG/Restricted/IAWG_Pilot_Studies/CCQM-P156.pdf). In addition, CCQM-K151/P191 (Determination of the amount content of a purity-assessed recombinant protein in an aqueous calibration solution) was begun in 2017 as a joint effort between the IAWG and the PAWG. In the more recent comparison, IAWG members quantitated sulfur in CCQM-P191 using IDMS as a proxy for the insulin analog under study, while the PAWG members quantitated the insulin analog through amino acid analysis in CCQM-K151. The results should be reported sometime in 2021. We expect there to be more opportunities for this sort of joint work between the IAWG and the PAWG or the NAWG.

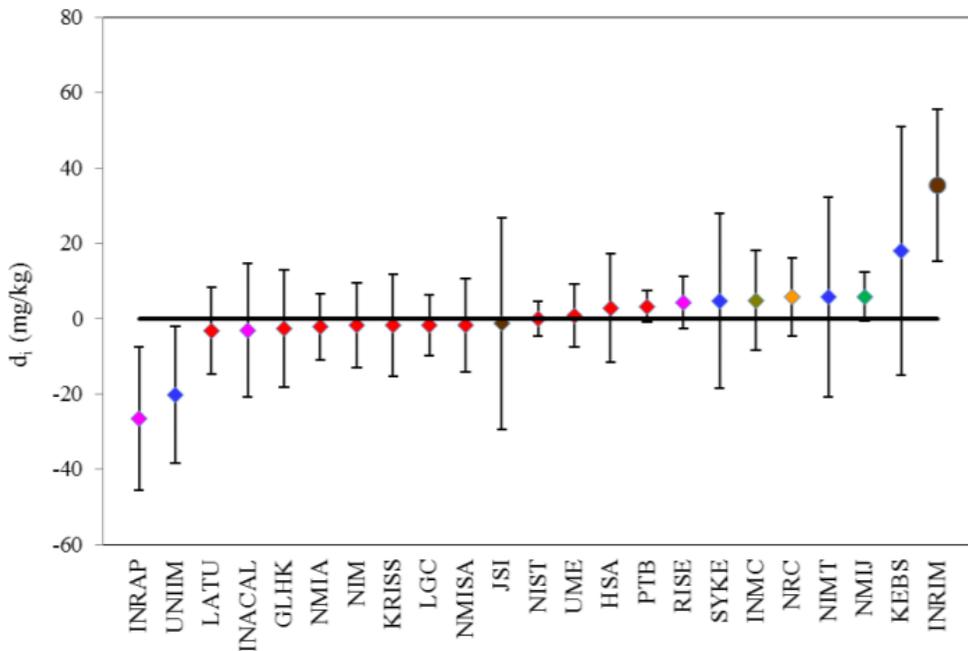
- **Small sample and spatially-resolved metrology** – To date the IAWG has held one workshop related to analyses of small samples or spatially-resolved analysis, that being a laser ablation workshop in April 2011. However, the IAWG has had no KCs or PSs on these topics, even though this type of metrology is extremely important in forensics, electronics, biology, and a host of other fields. Consequently, NMIs and DIs are expanding efforts to underpin measurements. The IAWG plans to perform PSs and KCs, as appropriate, to enable its member institutes to benchmark their capabilities to serve their stakeholders and to spur improvements in the relevant measurement methods. Already, the IAWG has slated a standalone PS on solid sample analysis to begin in 2023. Most participants are expected to employ laser ablation ICP-MS.
- **Elemental speciation** – Even though the IAWG has been involved with developing the metrological underpinning for practical and meaningful applications of elemental speciation analysis for two decades, there is still a need for further IAWG work. For example, the technique called speciated or species-specific IDMS usually relies upon chromatographic separation of the analyte from the matrix hyphenated online to ICP-MS analysis of the separated analyte. The addition of the required specially prepared isotope spike of a given analyte directly to the sample, instead of adding it online after the separation column, is a more advanced approach, providing better trueness. Only a few IAWG institutes are currently capable of performing the analysis this way. Therefore, there is a need for additional institutes to become experienced in this technique and for comparability of measurement capability to be demonstrated further. CCQM-K155/P196 (Elements and tributyl tin in seawater) began in 2019; CCQM-K158/P200 (Part B: Determination of inorganic arsenic in rice flour) began in 2020; and K162/P208 (Selenoproteins and total selenium in human serum) is in the final planning stages, set to begin in 2021.

IAWG Success Case #4 – CCQM-K145/P183 (Toxic and essential elements in bovine liver)

Problem: The IAWG periodically runs a ‘benchmarking’ comparison in which all member institutes are encouraged to participate. The purpose is to evaluate as broadly as possible the basic metrological capabilities of the members.

IAWG Activities: CCQM-K145/P183 (Toxic and essential elements in bovine liver) was selected as the latest benchmarking exercise. Zinc and nickel were the benchmark analytes, although the complete analyte list included other elements. Bovine liver was selected as the sample, because it represents high organic matrices, a category in which there is always strong interest within the IAWG. Bovine liver also relates well to two CIPM thrust areas, food safety and healthcare.

Outcome: CCQM-K145/P183 was completed in 2020. The results (zinc shown in the plot) demonstrated excellent equivalence of measurement capabilities.



5.2. IMPROVING STAKEHOLDER INVOLVEMENT

The end user beneficiaries of the IAWG’s activities are the users of the wide range of services provided by the IAWG’s participants as reflected in their CMC claims. The IAWG as a body does not normally consult directly with these end users, but such consultation on a national, regional or global level is undertaken regularly by all the NMIs and DIs participating in IAWG work. The outcome of these consultations governs their own programs and hence the IAWG activities which they propose and support. The IAWG has

implemented a formal process for capturing this sort of information by maintaining a database of reference materials and CMC claims planned by its member institutes. This database is updated annually and discussed at each IAWG meeting held in the Spring.

The range of services provided by IAWG members falls into five main areas:

- Production and certification of calibration standards and solutions
- Production and value assignment of matrix reference materials
- Organization of PT schemes and provision of reference values
- Provision of measurement and research services to meet local needs
- Establishment of knowledge transfer activities for metrologists and to meet the needs of local laboratories

Ultimately these services are essential to support all aspects of everyday life, including regulation, agriculture and manufacturing, trade, food, health, forensics, the environment, research and development, and so on. All the activities involve direct interaction with the field laboratories, which are the ultimate end users of the services, ensuring rapid and effective feedback of their needs. In addition, there is extensive consultation and collaboration, both formal and informal, to identify new measurement requirements, regulatory developments, technology trends, etc. This involves a very wide range of organizations and forums including, for example:

- National government departments or agencies
- Regional legislative bodies, such as the European Commission
- National and international standardization and accreditation bodies
- National and international trade or inspection organizations
- National and international professional organizations
- Scientific and technical conferences

The size and scope of the inorganic analysis programs operated by IAWG participants, as well as the nature and needs of their stakeholders, varies widely. However, in most parts of the world a key driver for NMI programs of inorganic chemical metrology is the need to underpin the wide spectrum of measurements required to establish and enforce legal regulations and similar governmental activities. The variety of stakeholder needs experienced by the IAWG's participants provides great strength in planning the IAWG's comparison schedule, because almost every possible situation around the world is reflected in the stakeholder feedback which they provide.

To summarize, while the IAWG does not interface directly with the end users of its services, a strong connection to them is provided through its member institutes. As needed, the IAWG may hold focused workshops with select end users to complement this arrangement.

5.3. PROMOTING GLOBAL COMPARABILITY

Since its inception, the IAWG has worked diligently to promote global comparability of measurement capabilities among its member institutes. In this context, it should be understood that global comparability includes both the demonstration of comparability and the improvement of capabilities that ultimately improves that comparability. As in the other CCQM WGs, both objectives are achieved in the IAWG through the body of KCs and PSs that are undertaken. The KCs form the primary basis for demonstration of global comparability of measurement capabilities, while the PSs form the primary basis for improvements in capabilities. The strong interactions among the various IAWG member institutes, which is a natural outcome of the CCQM, also plays a key role.

With the extremely broad measurement space associated with the IAWG's work, and with growth in the number of active institutes, it became clear well over a decade ago that the IAWG could not keep up with the demand for comparisons to underpin all of the desired CMC claims. Currently, the IAWG supports approximately 2000 approved CMC claims. The breakout of those CMC claims according to CMC category is shown in Figure 1.

To help deal with the problem of too many claims to underpin with limited resources, the IAWG has since 2009 implemented an approach to support CMC claims based on "core capabilities" demonstrated by participation in KCs (and selected PSs that are declared suitable to support CMC claims after their conclusion). The original version of the IAWG's core capability scheme viewed any measurement as a sequence of component parts, such as sample digestion, calibration, instrumental measurement, and so on. Under this scheme, a CMC claim could be supported by several key comparisons, each one contributing support for one or more component parts of the measurement associated with the CMC claim. While this original core capability approach was used for about a decade, reviewers of CMC claims found it cumbersome.

In response, around 2017 the IAWG decided to revise the core capability approach, again with the aims of reducing the number of KCs organised within the IAWG, simplifying the procedures for CMC claim submission and approval, and providing better support for broad scope CMC claims. The revision is still somewhat a developing topic, but the current approach is described here. Updates will always be made available on the IAWG web site.

The core capability approach is presently based on a matrix (see Figure 2) intended to assist with understanding how broadly a key comparison might be applied to support broad scope claims. The table is structured by matrix challenges and analyte groups, with most of the analyte groups based on the periodic table of the elements. The matrix table also indicates the analyte content range over which a capability has been demonstrated. When each new KC proposal is submitted to the IAWG for consideration, this matrix table will be prepared to list the analytes in

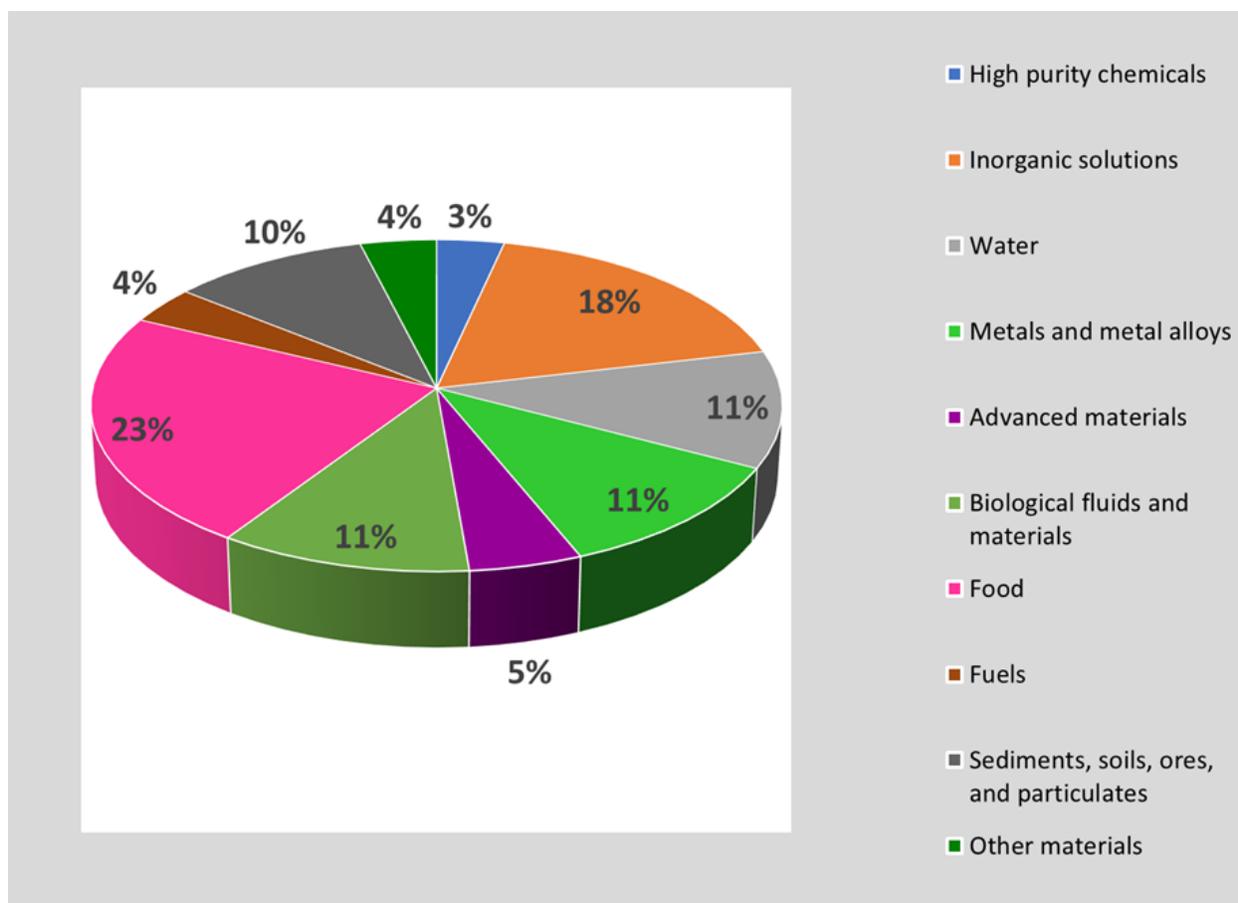


Figure 1. Approximate proportions according to CMC category of currently approved CMC claims as of September 2020 supported through the IAWG’s work program.

their respective locations in the matrix, together with the traditional “how far the light shines” statement. This approach will enable each KC to be planned to cover as much measurement space as possible, hopefully reducing the overall number of IAWG key comparisons that must be run. After the KC has been completed, both the matrix table and the “how far the light shines” statement will become part of the final report. Adjustments in the matrix table and the statement are allowed and even expected, because it is impossible for the IAWG to foresee all potential scenarios that might develop during the course of a KC’s execution.

The IAWG has also developed guidance to assist its member institutes in making CMC claims. Any CMC claim, of narrow or broad scope, is submitted according to the procedures laid out by the KCWG, along with a Record of Participation and a graph showing the performance of the institute relevant to the specific CMC claim being made (see Figure 3). For traditional narrow scope claims, the record of the institute over the past 5 y, or up to 7 y if needed, should be used. For broad scope claims, the record should be given over the past 10 y. Broad scope claims can be submitted by grouping multiple analytes and/or matrices, based on the matrix table approved for each relevant

KC. If there is adequate supporting evidence, a CMC claim could even be as broad as combining a complete matrix challenge with a complete analyte group, without listing individual analytes or matrices – e.g., group I and II elements in high organics content matrices. For a broad scope claim to be supported adequately by key comparison results, the institute must have participated in at least three studies over the 10 y period and the graphical performance record must show at least 90 % of the plotted points falling within the range -1 to +1. Such guidelines are intended to assist in the review of submitted CMC claims. Nevertheless, the review of broad scope claims will often require the input of technical experts.

The IAWG maintains a rolling, forward looking, program of comparisons that is updated and extended each year. Several requirements have been addressed to implement the program effectively:

- It is aimed to begin an average of three KCs per year, but there is no need for each active NMI/DI to participate in every comparison. The decision of a given institute to participate or not in each comparison is usually based on the perceived need to support CMC claims.
- The key factor, based on many years of experience in the IAWG, in allocating slots in the comparison schedule is the matrix challenge to be

Analyte groups	Matrix challenges						Calibration materials and solutions
	Water/aqueous	High silica content (e.g. Soils, sediments, plants, ...)	High salts content (e.g. Seawater, urine, ...)	High organics content (e.g. high carbon) (e.g. Food, blood/serum, cosmetics, ...)	Difficult to dissolve metals (Autocatalysts, ...)	High volatile matrices (e.g. solvents, fuels, ...)	
Group I and II: Alkali and alkaline earth elements (Li, Na, K, Rb, Cs, Be, Mg, Ca, Sr, Ba)							
Transition and post-transition elements (Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Y, Zr, Nb, Mo, Tc, Ag, Cd, Ta, W, Au, Hg, Al, Ga, In, Tl, Pb, Po)							
Platinum group elements (Ru, Rh, Pd, Os, Ir, Pt)							
Metalloids / Semi-metals (B, Si, Ge, As, Sb, Te, Se)							
Non-metals (P, S, C, N, O)							
Halogens (total element) (F, Cl, Br, I)							
Rare earth elements (Lanthanides, Actinides)							
Inorganic species (elemental, anions, cations)							
Small organo-metallics							
Proteins							
Nanoparticles							

Figure 2. The core capability matrix currently used by the IAWG.

addressed. However, the specific comparison to fill each slot is selected (and modified, if necessary) based on the analyte(s) which will be included. Specific attention is paid to designing each KC for the broadest practical application to broad scope CMC claims, as described above.

- The frequency with which slots are allocated to the various matrix challenges in general depends on the number of CMC claims for each challenge. With the new approach to broad scope CMC claims described above, however, it might be necessary to perform more comparisons in a less frequently visited matrix challenge type than would have been required previously. The IAWG seeks to balance these considerations with the specific needs of its participating institutes for supporting future CMC claims. The same approach is used regarding the various analyte categories represented in the matrix table.
- The allocation of slots and selection of specific comparisons are also informed by reference to the IAWG's annual survey and database of reference material production and CMC claim plans. The results of the survey and the database are reviewed once each year, usually at the Spring IAWG meeting.

Most KCs are conducted with parallel PSs. Such a parallel PS is often helpful to institutes which are relatively inexperienced in the specific measurements at hand or which do not plan to support CMC claims with the results.

- Standalone PSs are sometimes conducted by the IAWG as a first step toward conducting a full KC. This approach can be quite helpful for assessing the current state of comparability among the capabilities of the IAWG member institutes, thereby allowing a judgement to be made about whether the IAWG is ready for a KC. A standalone PS be an addition to the schedule or replace a planned KC.

The IAWG's rolling program plan for the years 2019-2023 is given in Annex 2. This plan is updated regularly and posted on the IAWG web site. Given the variety of factors that come into play, it is difficult to project the plan beyond 5 y. Two slots are allocated each year to new KCs that pose no unusual measurement challenges beyond what a laboratory with a well-rounded portfolio of measurements would normally face. (The IAWG calls these core KCs, while some other CCQM WGs call them Track A.) An additional slot is allocated each year for a new KC that does pose special measurement challenges, such as those for relatively new subfields of inorganic metrology (the IAWG refers to these as specialized KCs, instead of Track B); however, this slot may be occupied by another KC or PS if such a special challenge KC is not needed. There is also room each year for a standalone PS. The plan also accounts for whether the studies at hand are model 1

Record of Participation in CCQM Key Comparisons/Pilot Studies

Year Time Frame:
 Institute (country):
 Method:

KC or Pilot ID	Year	Analyte	Matrix	Units	x_i	u_i	$\%u_i$	d_i / U_i	Measurement technique/ Calibration approach	Analyte group	Matrix challenge

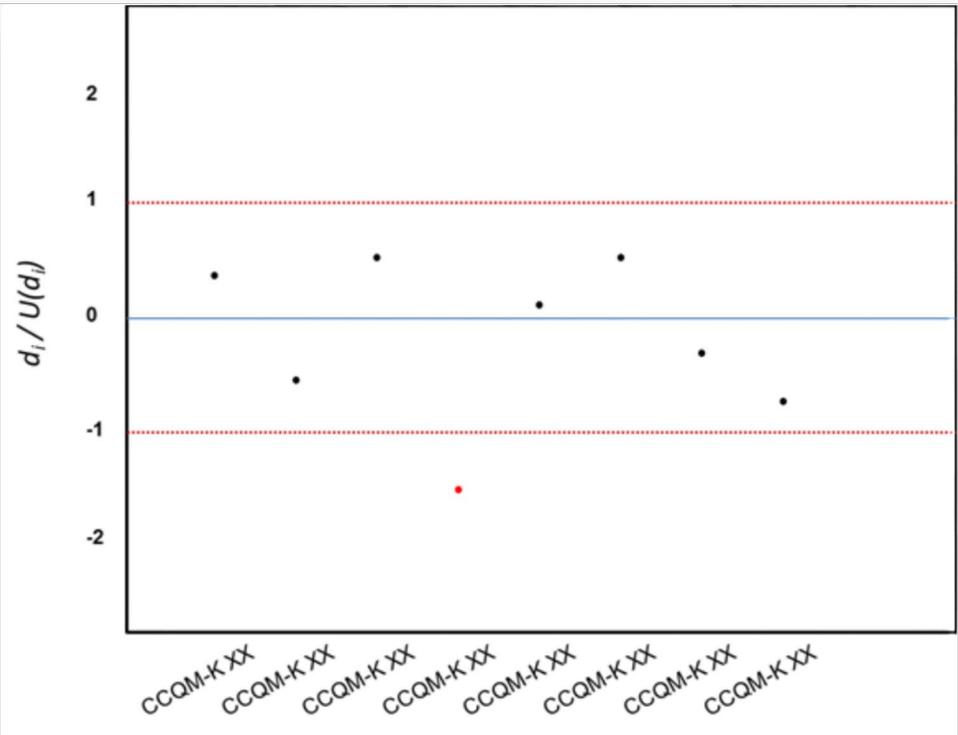


Figure 3. Record of Participation to be completed by institutes submitting CMC claims. For a traditional narrow scope claim, the time frame to be reported is the past 5 y, with the possibility of going to 7 y if needed. For a broad scope claim, the time frame is 10 y; there must be at least three points in the graph, and at least 90 % of those points must fall between -1 and +1 to support the broad scope claim; in the example given, the broad scope claim would not be acceptable.

or model 2. Model 1 refers to the case in which the pilot (i.e., coordinating) laboratory prepares samples to be measured by the participants, whereas model 2 refers to the case in which the participants prepare samples that are sent to the pilot laboratory for comparison.

The IAWG continues the practice of designating a KC as a ‘benchmark’ comparison about every five years. Benchmarks are selected to be relatively simple analyses unencumbered by strong interferences and other problems. In some cases, only selected analytes within a broader KC serve the function of the benchmark. The purpose of the benchmark comparisons is to get an overall sense of the measurement capabilities of the IAWG member institutes at a foundational level. Therefore, all IAWG institutes are encouraged to participate in these benchmark studies.

5.4. INTERACTION WITH RMO ACTIVITIES

The IAWG interacts with the various RMOs primarily through its members who are active in both the IAWG and in their respective RMOs. As appropriate, the IAWG incorporates into its work program the needs of the stakeholders in each RMO. Consideration is given on a case-by-case basis to whether the needs are specific to one RMO or apply equally well to other RMOs. If the former, then activities are better undertaken as RMO supplementary comparisons and related metrology programs. If the latter, then such activities might better be undertaken within the IAWG program.

The work programs of the RMOs are probably influenced more by the IAWG work program than the other way around. This is a result of the role of each RMO in (1) providing key comparisons that can be linked to IAWG key comparisons to expand the opportunities afforded to the NMIs/DIs in its region and (2) providing supplementary comparisons to complement the IAWG program of work. The RMOs serve these purposes very well, enhancing the effectiveness of the CCQM overall.

Nevertheless, some RMO activities do influence IAWG activities. For example, EURAMET set up several coordination mechanisms to ensure that Europe’s metrology infrastructure and networks develop in a way that enhance industrial innovation, competitiveness and international trade, as well as to respond to grand societal challenges. Joint research projects (JRPs) under the European Metrology Research Programme (EMRP) and the European Metrology Program for Innovation and Research (EMPIR) and the establishment of joint structures that go beyond joint research, called European Metrology Networks (EMN), in the next program (European Partnership in Metrology), contribute to address the EU metrological needs. In the chemistry and biology areas, the activities are mainly related to societal challenges in health, climate change and environment, energy, food and nutrition and aim to underpin regulation and standardization.

Some IAWG and EURAMET comparisons have been organized as outcomes of the projects run within EMRP/EMPIR:

- CCQM-P149 (Estimation of impurities for the overall purity evaluation of zinc) was conducted as an IAWG standalone PS as an outcome of the project “Primary standards for challenging elements, SIB09.”
- CCQM-P194 (Number concentration of colloidal nanoparticles in liquid suspension) was organized by the IAWG as an outcome of the “Metrology for innovative nanoparticles” (InNanoPart) project.
- EURAMET.QMS11 (Elements in river water) was organised as a supplementary comparison as an outcome of the project “Matrix reference materials for environmental analysis (ENVCRM).”

The impact of the IAWG PSs is that the measurement capabilities developed within the EURAMET projects were validated globally. In turn, the IAWG work program was strengthened by its connection to the EURAMET work program. Thus, the synergy was beneficial to both entities. It is expected that in the future other comparisons will be organised in strategic sectors where analytical challenges have been raised, such as nanometrology or food safety.

ANNEX

1. GENERAL INFORMATION

A snapshot of the IAWG:

CC Name: CCQM

CC Working Group: Inorganic Analysis Working Group (IAWG); established in 1997

Number of Members: 31 institutes representing a total of 27 countries have designated contact persons to the IAWG as of September 2020

Number of Participants at last meeting: 70 persons from 30 institutes

Periodicity between Meetings: Approximately every six months, although web meetings may be held more frequently as needed

Date of last full meeting: 02-04 November 2020 (web meeting over three days)

CC WG Chair (Name, Institute, and years in post): Dr Michael Winchester, NIST, 1.5 y

Number of KCs organized (up to and including 2020): 71

Number of Pilot studies organized (up to and including 2020): 104

Number of CMCs published in KCDB supported by CC body activities (up to and including 2020): 2,000 (thought to be accurate to the hundred)

IAWG Terms of Reference

The responsibilities of the IAWG are:

(1) To carry out key comparisons, and where necessary pilot studies, to critically evaluate and benchmark NMI/DI claimed competencies for the amount of substance fraction or mass fraction measurements of the elements, cations and anions, inorganic compounds, and organo-metallic compounds in matrices which include pure materials, calibration solutions and complex samples, such as those used for matrix reference materials; providing demonstrable evidence of the validity and international equivalence of NMI measurement services offered to customers. (Note: Until the formation of the IRWG in 2018, measurements of isotopes and isotope ratios were also included.)

(2) To identify and carry out interlaboratory work and pilot studies required to underpin the development of reference measurement systems in the field of inorganic chemical metrology, of the highest possible metrological order with traceability to the SI, where feasible, or to other internationally agreed units, to support NMI/DI measurement services being developed in response to customer needs.

(3) To act as a forum for the exchange of information about the research and measurement service delivery programs and other technical activities of the WG members in inorganic chemical metrology, thereby creating new opportunities for collaboration.

2. LIST OF PLANNED KEY AND SUPPLEMENTARY COMPARISONS AND PILOT STUDIES

For planning, the IAWG employs a rolling program of KCs and PSs that is updated regularly (see Figure 4). When this plan is revised, it is uploaded onto the IAWG web site, so that the latest version is always available.

Period	Model 1 Comparisons			Model 2
	Core key comparisons Core Capabilities model – KC/Sample matrix – CMC cat.	Specialised key comparisons	Pilot studies	
2019	High salts content K155/Elements in seawater [5, 10]	Difficult to dissolve metals + metal oxides K144/Alumina powder [8, 9, 14]	K152/Assay/Purity of potassium iodate [1]	(2017-2018) K143
2020	Difficult to dissolve metals + metal oxides K160/PGE in Autocatalyst [8, 9, 14]	High salts content K161/Anions in seawater [5]	K169 / Number concentration nanoparticles [9]	
2021	High organics content K158/Elements and As speciation in grain powder [11]	Water KXXX [5]	K162 / Selenoproteins in serum [10]	As speciation in seafood P215 [10]
2022	High volatile matrices KXXX [12]	High salts content [10, 11]		PXXX Non-metallic impurities [8]
2023	High organics content KXXX [10, 11]	High silica content KXXX [13]		Solid sample analysis by LA-ICP-MS

Figure 4. Rolling program planning tool used by the IAWG, showing planned studies, at the time of this writing, over the period 2019 through 2023.

3. SUMMARY OF WORK ACCOMPLISHED AND IMPACT ACHIEVED (2017-2020)

The IAWG made good progress in its work in the period 2017-2020. In efforts to advance inorganic measurement science, the working group held several workshops in conjunction with IAWG meetings, as given in Table 1. As indicated by the list of workshops, the greatest emphasis was placed on developing metrology for nanoparticles. The two workshops directed toward measurements of number concentrations of nanoparticles suspended in liquid suspension were valuable for evaluating the state of this important area of measurement science. CCQM-P194 [Suspension of colloidal gold nanoparticles (citrate capped) in water], the subject of one of these workshops, was an especially important standalone PS that demonstrated the excellent comparability of results among the participants in both the IAWG and the SAWG using complementary techniques. Effectively, the PS served as a validation at the CCQM level of

spICP-MS for the particular measurand. This has led to CCQM-K166/P210 (Measurement of nanoparticle number concentration in liquid suspension), jointly registered to both working groups and now being organized, to document this comparability to support CMC claims. As stated earlier, the IAWG plans to continue to focus attention on nanoparticle metrology in the future.

Table 1. Workshops held at IAWG meetings in the years 2017 through 2020.

IAWG Meeting	Workshop
April 2017	Measurement of nanoparticle number concentration in colloidal suspension
September 2017	Inorganic nanoparticles in food and other matrices
April 2018	Complementary protein analysis techniques used by IAWG and PAWG
October 2018	Novel mass spectrometry for inorganic analysis
April 2019	CCQM-P194: Number concentration of colloidal particles in solution (presentations by participants)
September 2019	Direct and indirect approaches to the purity assessment of high purity metals and salts

Table 1 also shows that a workshop was held to explore the complementary nature of the techniques commonly employed by the IAWG member institutes and those commonly employed by the PAWG members for protein analysis. This workshop was motivated by CCQM-K151/P191 (Mass fraction of a purity-assessed recombinant protein in an aqueous calibration solution using amino acid-based ID-LC-MS and/or sulfur-based ID-ICP-MS). The results of this comparison, still being prepared, show how the IAWG and the PAWG can support one another for measurements of biomolecules. This success is why the two working groups are planning to continue working together.

The workshop in September 2019 on purity assessment of high purity materials represents the latest in a long series of workshops and activities over many years on calibrants and SI-traceability for inorganic analysis. It is noteworthy that April 2017 saw the publication of the IAWG guidance document titled “Roadmap for the purity determination of pure metallic elements: Basic principles and helpful advice” found at https://www.bipm.org/wg/CCQM/IAWG/Allowed/April_2017/CCQM-IAWG17-28.pdf. This document represents the culmination of years of IAWG work to provide guidance to inorganic analysis practitioners on how to evaluate properly the purity of high purity inorganic metals. While this is a major accomplishment, there is still more to be done in this field, justifying the IAWG’s continuing efforts.

The novel mass spectrometry workshop held in October 2018 highlighted recent advances in mass spectrometry presented by speakers from outside the IAWG members, including one from a government agency and three from universities. Indeed, the workshop on nanoparticles in food and other matrices also included speakers from outside the IAWG’s member. Both were good faith efforts to provide direct contact between the IAWG and such nonmember entities.

In the area of promoting global comparability in the period 2017 through 2020, the IAWG has worked on the KCs and parallel PSs listed in Table 2. As shown by the large number of rows in

the table, the IAWG continues to have a heavy workload (23 CCQM comparisons), despite efforts to reduce the workload over the last several years. Even though the IAWG aims to begin no more than three KCs in any given year, the actual number of active comparisons at any time averages about six. In addition, IAWG member institutes are participating in some RMO comparisons, which are also listed at the bottom of Table 2 for 2017 – 2020. This information implies that the IAWG must continue to try to reduce the number of studies it takes on. The comparisons listed in Table 2 are categorized according to CMC category in Figure 5.

Standalone PSs worked on by the IAWG in the period 2017 – 2020 include CCQM-P149 (Estimation of impurities for the overall purity evaluation of zinc), CCQM-P156 (Element-based quantification and purity analysis of a dNMP standard solution), and CCQM-P194 (Number concentration of colloidal nanoparticles in liquid suspension), all of which have already been discussed in this strategy document. In addition to these, the IAWG has also worked on CCQM-P160 (Isotope ratios / molar mass measurements of silicon isotopes in isotopically enriched silicon) before its transfer to the IRWG formed in 2018. Finally, CCQM-P201 (Total haemoglobin concentration in human whole blood), a study jointly registered in the IAWG and the PAWG, is now in progress.

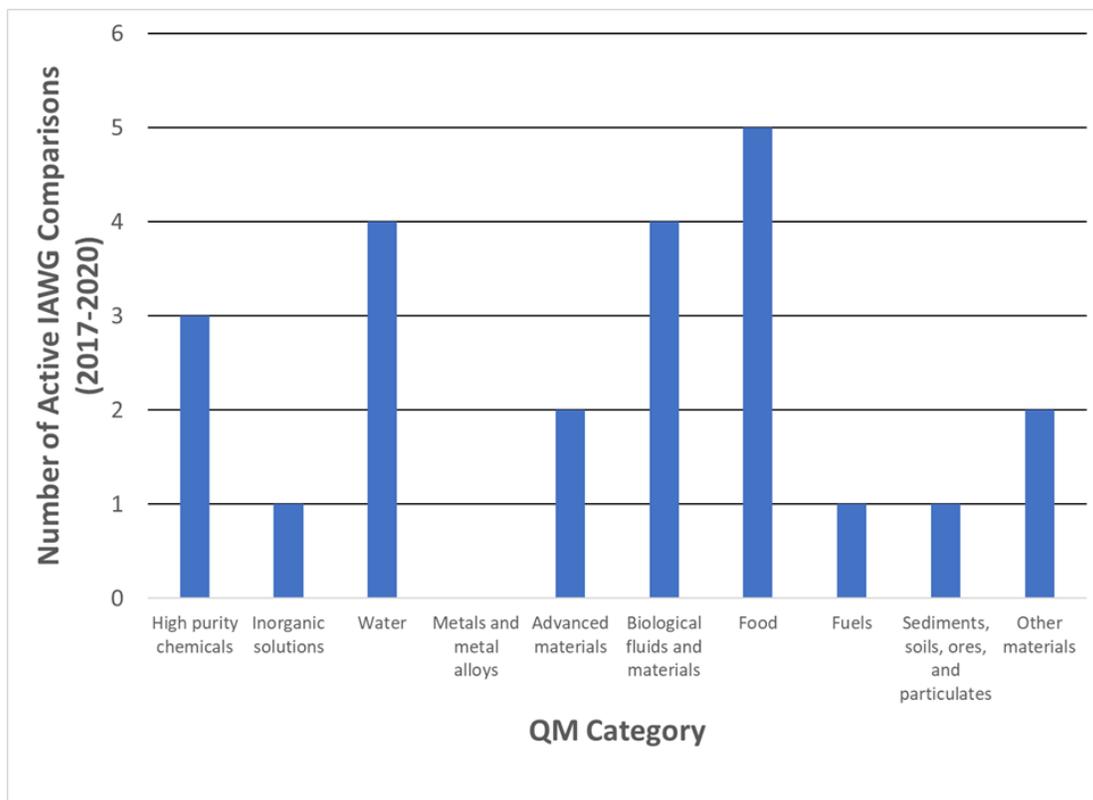


Figure 5. Number of CCQM KCs worked on by the IAWG in the period 2017-2020 according to CMC category. The KCs are listed in Table 2.

Table 2. Key comparisons and parallel pilot studies on which the IAWG worked in the period 2017 through 2020. The relevant RMO supplementary comparisons for the same time period are given at the bottom.

Designation	Title	Registration	Status ^a
CCQM-K34.2016	Assay of potassium hydrogen phthalate (KHP)	2017 ^b	Approved for equivalence (2018)
CCQM-K34.2016.1	Assay of potassium hydrogen phthalate (KHP)	2019 ^b	Draft B report
CCQM-K108.2014/P171	Determination of arsenic species and total arsenic in brown rice flour	2015	Approved for equivalence (2017)
CCQM-K122/P135.1	Anionic impurities (bromide, sulfate) and lead in salt solutions	2014	Approved for equivalence (2020)
CCQM-K123/P157	Trace elements in biodiesel fuel	2014	Approved for equivalence (2017)
CCQM-K124/P158	Trace elements and chromium speciation in drinking water	2014	Approved for equivalence (2017)
CCQM-K125/P159	Iodine and other elements in infant formula	2015	Approved for equivalence (2017)
CCQM-K127/P162	Contaminant and other elements in soil	2015	Approved for equivalence (2017)
CCQM-K128/P163	Heavy metals and organo-tin in leather powder	2015	Approved for equivalence (2018)
CCQM-K139/P173	Comparison of the measurement of clinical markers in human serum	2017	Approved for equivalence (2018)
CCQM-K144/P182	Analysis of elemental impurities in alumina powder	2018	Draft B report
CCQM-K140/P175	Carbon isotope ratio delta values in honey	2016	Approved for equivalence (2017)
CCQM-K143/P181	Comparison of copper calibration solutions prepared by NMIs/DIs	2016	Draft B report
CCQM-K145/P183	Toxic and essential elements in bovine liver powder	2017	Approved for equivalence (2020)
CCQM-K149	Nitrogen in milk powder	2017	Approved for equivalence (2019)
CCQM-K151/P191	Mass fraction of a purity-assessed recombinant protein in an aqueous calibration solution using amino acid-based ID-LC-MS and/or sulfur-based ID-ICP-MS	2017 ^c	Draft B report
CCQM-K152/P192	Purity assessment of high purity potassium iodate	2018 ^b	Draft B report
CCQM-K155/P196	Elements and tributyl tin in seawater	2019	Draft A report
CCQM-K158/P200	Measurement of a range of spiked and natural elements in rice material in addition to strontium (with natural isotope ratios), associated rubidium and inorganic arsenic	2020	Planned
CCQM-K160/P203	Platinum group elements in automotive catalyst	2019	Planned
CCQM-K161/P207	Anions in seawater	2020	Planned
CCQM-K162/P208	Selenoproteins and total selenium in human serum	2020	Planned
CCQM-K166/P210	Measurement of nanoparticle number concentration in liquid suspension	2020	Planned
APMP.QM-S10/P31	Elements in food supplement	2016	Approved for equivalence (2019)
APMP.QM-S19	Elements in lipstick material	2019	Planned
EURAMET.QM-S11	Elements in river water	2017	Planned
SIM.QM-S7	Trace metals in drinking water	2016	Approved for equivalence (2018)
SIM.QM-S8	Trace metals in drinking water	2017	Approved for equivalence (2018)
SIM.QM-S10	Elements in milk powder	2019	Planned

^a As of September 2020.

^b Jointly registered to the IAWG and the EAWG

^c Jointly registered to the IAWG and the PAWG

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5. DOCUMENT REVISION HISTORY

Document version; type of revisions; date

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