

## Consultative Committee for Ionizing Radiation (CCRI)

President: W. Louw

Executive Secretary: S. Judge

### 1. Executive summary

The CCRI is responsible for coordinating and supporting metrology for all applications of ionizing radiation. The science helps ensure that ionizing radiation can be used safely and effectively in healthcare, environmental health and safety, the nuclear industry and the defence sectors. Every year, ionizing radiation metrology affects 4 million cancer patients, 4 billion patients undergoing diagnostic x-rays and nuclear medicine scans and 11 million radiation workers. Accurate metrology is also essential for effective sterilization of medical devices (40 % of single-use medical devices are sterilized by ionizing radiation) and assuring the quality of radiation-processed materials. The work of the CCRI underpins all of these applications, by enabling the accurate measurement of radiation dose and radioactivity.

The cornerstone of the CCRI's work is organizing comparisons to demonstrate the equivalence of national measurement standards, so that Member States can calibrate radiation detection instrumentation accurately for checking the radiation doses and radioactivity to which patients, the workforce and the public are exposed. The CCRI works closely with the Ionizing Radiation Department at the BIPM, which provides the scientific facilities for more than 60 % of the comparisons in ionizing radiation metrology.

The CCRI strategy for 2013 to 2023 covers the development of standards for new applications, improvements in the efficiency of the international measurement system for radionuclide metrology and reducing costs for all stakeholders by joint utilization of facilities. The main achievements during the last 4 years include:

- A new standard for absorbed-dose-to-water in kilovoltage x-rays has been developed for comparisons with national laboratories that hold standards for radiotherapy using this energy range.
- The established pattern of comparisons has continued, including 37 comparisons for radiation dosimetry and 21 for long-lived radionuclides at the BIPM. Comparisons have also been completed for the first time for some short-lived radionuclides used in medical imaging ( $^{11}\text{C}$  and  $^{64}\text{Cu}$ ).
- The challenge of establishing international traceability for high-energy photon dosimetry (with linear accelerators) has been addressed. The BIPM has arranged access to an accelerator at a new local research facility (DOSEO); a comparison service has been established and measurements have been completed for comparisons with two NMIs.
- The organization of the CCRI has been streamlined and the membership rules were aligned with the other CCs. All NMIs with major ionizing radiation metrology facilities are now included in the CCRI and the biennial meeting schedule has been reduced from 20 working days in 2014 to 10 in 2016. A further reduction is planned for 2019.
- A special issue of *Metrologia* on *Uncertainties in Radionuclide Metrology* has been published. In addition, Volume 8 of the *Monographie BIPM 5, Table of Radionuclides*, has been published. The CCRI played a key role in ensuring the adoption of new data for radiation dosimetry published in *ICRU Report 90*. A review article to assist NMIs in adopting these new data was published in *Metrologia*.
- There has been an increased focus on knowledge transfer and capacity building activities, with a programme of secondments and visits to the BIPM, participation in

conferences and workshops such as those organized by the IAEA, and the organization of new workshops.

The number of CMCs remains stable at around 4 000, but this large number of CMCs can result in a significant workload for the NMI staff responsible for periodic reviews. The CCRI is continuing to seek approaches to address this workload, whilst adhering to the principles of the CIPM MRA. Any changes need to be made without reducing the quality of the CMCs and balancing the needs of both large and small NMIs. A concept of “representative” CMCs is being considered that increases the number of services that can be covered by a single CMC.

A new strategy for the CCRI has been developed, to take into account the future requirements driven by developments in technology such as new radiotherapy methods and new drugs for radioimmunotherapy, and concerns of the potential risk to the environment from the large quantities of radioactive waste that will be generated from the decommissioning of legacy nuclear sites.

## **2. Scope of the CC**

The CCRI’s vision is a world in which ionizing radiation can be used for the benefit of humankind, confident that the associated risks are constrained by accurate, scientifically-rigorous, measurement. Its mission is to discuss, foster, enable and coordinate the development, comparison and promulgation of national measurement standards for ionizing radiation. The CCRI aims to enable all users of ionizing radiation to make measurements at an accuracy that is fit-for-purpose, working with its stakeholders to be ‘the voice of the customer’.

The scope of the work encompasses metrology for all applications of ionizing radiation, including dosimetry for radioprotection, radiotherapy and medical device sterilization, and radionuclide metrology for nuclear medicine and environmental protection. All ionizing radiation is included in the scope: alpha and beta particles, gamma- and x-rays, electrons, protons and heavier ions, and neutrons.

The CCRI’s main tasks and deliverables are to:

- Plan and run comparisons, published in the Technical Supplement of *Metrologia*, including approving Key Comparison Reference Values (KCRVs),
- Produce guidance for NMIs, DIs and RMOs on CMCs and comparisons,
- Maintain and develop the international reference systems for radionuclide metrology (SIR, SIRTI and ESIR),
- Maintain and develop measurement standards for radiation dosimetry,
- Publish monographs on nuclear decay data and special issues of *Metrologia*,
- Contribute to conferences and meetings,
- Contribute to knowledge transfer, for example, by facilitating secondments and visits to the BIPM and through organizing workshops.

## **3. Strategy**

The CCRI’s long-term strategy was discussed at a Strategy Workshop held on 21 June 2017, which led to the formation of the CCRI *ad hoc* Working Group on Strategy (CCRI-SWG). This Working Group held its first meeting on 16 March 2018.

In line with the CCRI's vision, the new 2018-2028 strategy is aiming for an inclusive international measurement system for ionizing radiation. The main aims of the CCRI strategy are:

**To improve global comparability of measurements** by: making comparison exercises more accessible and more efficient; increasing the scope to cover emerging requirements; reducing the need for long-term, large-scale exercises; and optimizing the use of resources at NMIs / DIs and the BIPM.

**To build capability in smaller NMIs**, by organizing knowledge transfer workshops and increasing secondments and visits to the BIPM working in partnership with NMIs / DIs and liaison organizations such as the IAEA.

**To advance the state of the art for priority issues of benefit to NMIs**, through supporting the organization of targeted joint research projects.

#### 4. **Activities and achievements since the last meeting of the CGPM**

The CCRI has held two meetings since the 25th meeting of the CGPM: 17 May 2015 and 29-30 June 2017. Both meetings were presided over by Dr Wynand Louw.

The CCRI was streamlined in 2016/2017. The three Sections, which cover radiation dosimetry, radionuclide metrology and neutron metrology, now function under the auspices of the CCRI committee as Working Groups. The technical working groups (such as the Key Comparison Working Groups) continue to report to the relevant Sections, with the over-arching CCRI *ad hoc* Working Group on Strategy (CCRI-SWG) and CCRI RMO Working Group on IR CMCs (CCRI-RMOWG) reporting to the CCRI. The first meeting in the new format was held in 2017 where the duration of the meetings was reduced to 10 working days (compared to 20 in 2014). It is planned to further consolidate the meetings in 2019 to fit within one week.

The CCRI works closely with staff at the BIPM to deliver comparison exercises and to help steer development projects; this partnership reduces the burden on NMIs / DIs to organize comparison exercises and facilitates knowledge transfer activities.

##### 4.1. Main activities

As reported to the 25th meeting of the CGPM, the number of CMCs remains relatively stable at around 4 000. Although there are relatively few new CMCs submitted every year, the large number of CMCs means that the requirement for periodic reviews can be burdensome on some NMI staff, depending on details of the review processes within the RMO. There have therefore been extensive discussions concerning the implementation of the findings from the review of the CIPM MRA. Efforts to simplify the interpretation of CMCs are continuing by trying to balance the interests of larger NMIs, which need to reduce the complexity of reviewing CMCs, with the needs of smaller NMIs where direct links to services can be established easily under the current definition. Guidance has been discussed at the CCRI but there is further work to be done on this topic.

There has been progress in implementing a clear strategy for comparisons. A 15-year cycle of comparisons has been agreed, with procedures in place to ensure that one comparison exercise can be used to underpin several CMCs (the Measurement Methods Matrix used in radioactivity being one example). The regular cycle of comparisons for radiation dosimetry has continued,

with 37 comparisons being carried out during the period, enabling NMIs to demonstrate the continued accuracy of their primary standards.

One major issue of concern to the CCRI in recent years has been establishing a firm basis for traceability for dosimetry for accelerator-based radiotherapy. Accelerators are rapidly replacing high-activity sealed sources for radiotherapy; there are already 12 000 accelerators in use compared to 2 000 sealed sources, and there is growing demand for comparisons and calibrations. An arrangement has been reached between the BIPM and a research facility (DOSEO) for access to a linear accelerator: the BIPM primary standard has been validated on the facility, and a comparison service was launched in 2017. The fortunate proximity of this new French facility to the BIPM has enabled BIPM staff to set up the comparison service with no loss in accuracy and efficiency. Two NMIs (the KRISS (Republic of Korea) and the METAS (Switzerland)) have already participated.

A number of NMIs have developed primary standards for absorbed dose-to-water in medium-energy x-ray beams. To comply with the needs of the NMIs to compare and validate their standards, a new service, based on the existing free-air primary standard, has been established at the BIPM. A new key comparison was approved by the CCRI(I) and registered in the KCDB as BIPM.RI(I)-K9. The first comparison was completed in 2017 with the PTB (Germany) and the second with the LNH (France) is in progress.

Comparisons of standards of gamma-ray emitting radionuclides have continued using the Système Internationale de Référence (SIR) and an equivalent transportable instrument (SIRTI). Both instruments are established and convenient approaches to demonstrate equivalence, reducing the need for large-scale comparison exercises; the CCRI approved updates of the KCRVs for 16 radionuclides, including, for the first time, results from the  $^{99m}\text{Tc}$  and  $^{18}\text{F}$  SIRTI comparisons.

The SIR played an important role in demonstrating the equivalence of primary standards of  $^{223}\text{Ra}$  (a new therapeutic agent) – this radionuclide is particularly difficult to standardize and the comparison enabled NMIs to confirm their standards, supporting the roll-out of the new drug world-wide.

The SIR is not suitable for use with short-lived radionuclides as they decay during transit to the BIPM. However, diagnostic imaging in nuclear medicine uses radiopharmaceuticals based on such short-lived isotopes. The CCRI therefore supported the development of a travelling instrument (SIRTI) that can be taken to NMIs for comparison exercises; the instrument has been used to compare standards of  $^{11}\text{C}$  and  $^{64}\text{Cu}$  for the first time, and has been used at ANSTO (Australia), NRC (Canada), NIST (USA), POLATOM (Poland) and NMISA (South Africa). A strategic approach to using the SIRTI has been agreed by the Key Comparison Working Group of Section II (CCRI(II)-KCWG(II)), priority radionuclides have been identified and new measurement campaigns will be launched in the 2020-2023 work programme.

The CCRI co-ordinated the publication of a *Metrologia* Special Issue on *Uncertainties in Radionuclide Metrology* (Volume 52, Number 3). This publication covers the estimation of uncertainties across the field, including articles that are of use in nuclear medicine clinics (ionization chambers) and environmental monitoring laboratories (gamma-ray spectrometry). The latter article has been referred to in a draft ISO standard on gamma-ray spectrometry, and will consequently be used in testing laboratories world-wide.

The period also saw the publication of new recommended values for basic quantities related to the interaction of radiation with matter for radiation dosimetry (ICRU Report 90, *Key Data for*

*Ionizing-Radiation Dosimetry: Measurement Standards and Applications*). Research work carried out at the BIPM made an important contribution to these new recommendations. The CCRI has been instrumental in disseminating the use of these new data to the metrology and user communities, particularly through the publication by the BIPM of a review article in *Metrologia*, 2018, **55**(4)<sup>1</sup> ensuring that estimates of patient dose continue to be based on the best available scientific data.

A further volume of nuclear decay data has been published as a *BIPM Monographie* (BIPM-5, Volume 8, 2016) covering recommended decay data for 32 radionuclides. The decay data are evaluated by the Decay Data Evaluation Project, led by LNHB (France) with the participation of institutes world-wide; publication as a BIPM monograph ensures that national measurement institutes (and hence most measurement laboratories) adopt the data. This work has helped to harmonize measurements of radionuclides: prior to publication as a *BIPM Monographie*, laboratories used different values drawn from a wide range of publications and databases.

There is a long-standing knowledge transfer scheme in place: participants in dosimetry comparison and calibration exercises often work alongside BIPM staff to carry out the measurements, including staff from ENEA (Italy), ININ (Mexico), SCK (Belgium), SMU (Slovakia), KRISS (Republic of Korea), METAS (Switzerland) and NRC (Canada). This has been supplemented by secondees working at the BIPM on longer-term projects.

A joint workshop with representatives from the CCEM was held at NIST in September 2018, to discuss opportunities to use new low electrical current measurement technologies for instruments used in radionuclide metrology. Twenty delegates attended from the radionuclide metrology and electrical metrology communities, and the conclusion was that two approaches showed promise. The workshop will be published as *NIST Conference Proceedings*, and a study of one of the techniques will start at the BIPM in 2019. If successful, the new technology could enable NMIs to replace obsolete electronics and reduce the dependence on sealed radioactive sources for ionization chambers.

#### 4.2. Challenges and difficulties

There are two external regulatory challenges to maintaining the international measurement system in its present form. First, shipping radioactive sources for comparisons can be very complex and time consuming due to “multiple layers of regulations, lack of harmonization and over-regulation in transport authorities”<sup>2</sup>. This applies in particular to comparisons of neutron source emission, but shipments of radioactive sources are also impacted. Work is under way to address this issue where possible, for example, by setting up an on-demand comparison service for beta-emitting radionuclides similar to the SIR. This project is not without its own technical challenges; the trial exercises in 2014 and 2017 gave inconsistent results. The project restarted at the BIPM in September 2018, with support from a dedicated team of experts from the LNHB, POLATOM, PTB and NPL, the end-goal of simplifying comparisons of important radionuclides with applications in nuclear medicine is making the effort worthwhile.

The second challenge comes from the increasingly stringent regulations on the use of high-activity sealed sources. Such sources are used in dosimetry (to produce reliable photon

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<sup>1</sup> Burns D., Kessler C., Re-evaluation of the BIPM international dosimetry standards on adoption of the recommendations of ICRU Report 90, *Metrologia*, 2018, **55**(4), R21-R26

<sup>2</sup> <http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/transport-of-nuclear-materials/transport-of-radioactive-materials.aspx#ECSArticleLink4>

beams for comparison exercises) and in radioactivity (to check the reproducibility of measurements in ionization chambers). The approach being taken is to share resources where feasible: the  $^{137}\text{Cs}$  irradiator had to be closed at the BIPM to comply with these regulations, and work is starting for the transfer of the BIPM standard to the IAEA. The  $^{137}\text{Cs}$  beam provides an essential high-energy comparison point for radiation protection standards: the service will continue to be run by BIPM staff using the BIPM primary standard and any increase in uncertainties due to the transfer are expected to be negligible for radiation protection dosimetry. The search is also on to find replacements for legacy sealed sources used in radionuclide metrology - an IRA/NPL/LNHB joint project has been launched to construct  $^{166\text{m}}\text{Ho}$  sources to replace  $^{226}\text{Ra}$  for the SIR and similar instruments at NMIs.

## 5. Outlook in the short and long term

In the short term, the focus of the CCRI will be on addressing the key issues impacting the field (ensuring there are efficient and effective processes for reviewing CMCs, reducing the number of large-scale comparison exercises and reducing the dependence on sealed sources).

For the longer term, the drivers for ionizing radiation metrology remain strong and will bring the need for new comparisons and new science:

- Expansion in the use of new radiotherapy techniques (including proton therapy), leading to the need for new primary dosimetry standards and associated comparisons,
- Continued expansion in the use of diagnostic medical examinations,
- Concerns over radioprotection issues for workers, patients and the general public,
- Miniaturization of electronic devices making them more susceptible to the effects of radiation damage,
- New industrial applications of high-dose irradiations,
- Development of new therapeutic radiopharmaceuticals (radioimmunotherapy), requiring primary standards and techniques for comparing standards of the radionuclides,
- Growth in the work for clearing legacy nuclear sites, testing land quality and tighter regulations for naturally-occurring radionuclides, resulting in an increase in the need for comparisons of very long-lived radionuclides,
- Metrology for the next generation of nuclear power stations, including fusion reactors,
- Demands for high accuracy measurements for characterizing samples of illicit radioactive materials (nuclear forensics).

Finally, the CCRI expects closer links to develop with the IAEA, as the major international organization working in the field.

### Annex: CC Data

**The CCRI** was first set up in 1958  
(From 1958 to 1999 the committee was under the name CCEMRI.)

President: W. Louw

Executive secretary: S. Judge

#### **Membership:**

Eight members, three liaison organizations and 14 observers

List of CCRI members and observers:

<https://www.bipm.org/en/committees/cc/ccri/members-cc.html>

Meetings since the 24th CGPM meeting: 17 May 2015 / 29-30 June 2017

Full reports of the CCRI meetings: <https://www.bipm.org/en/committees/cc/ccri/publications-cc.html>

Three Sections:

CCRI Section I X- and gamma rays, charged particles  
 CCRI Section II Measurement of radionuclides  
 CCRI Section III Neutron Measurements

Seven Working Groups

CCRI-SWG CCRI *ad hoc* Working Group on Strategy  
 CCRI-RMOWG Working Group on IR CMCs  
 CCRI(I)-BSWG(I) Brachytherapy Standards Working Group  
 CCRI(I)-KCWG(I) Key Comparisons Working Group (Section I)  
 CCRI(II)-KCWG(II) Key Comparisons Working Group (Section II)  
 CCRI(III)-KCWG(III) Key Comparisons Working Group (Section III)  
 CCRI(II)-ESWG(II) Extension of the SIR to beta emitters Working Group

CCRI Comparison activity	Completed	In progress	Planned [2019-2023]
CCRI key comparisons (and supplementary comparisons)	8+(0)	4+(6)	1 per year (Section II)
BIPM comparisons	51	14 (dosimetry) Xx (radioactivity) (See Note 2)	20 per year (see Note 1)
CC pilot studies	0	4	1 (pilot study for ESIR)
CMCs	3985 CMCs registered in the KCDB		

Notes

1. The BIPM offers the following comparisons, available on request:

Identifier	Quantity
BIPM.RI(I)-K1	Air kerma - <sup>60</sup> Co
BIPM.RI(I)-K2	Air kerma – low energy X-rays
BIPM.RI(I)-K3	Air kerma – medium energy X-rays
BIPM.RI(I)-K4	Absorbed dose to water – <sup>60</sup> Co
BIPM.RI(I)-K5	Air kerma – <sup>137</sup> Cs
BIPM.RI(I)-K6	Absorbed dose to water – high energy photons
BIPM.RI(I)-K7	Air kerma - mammography
BIPM.RI(I)-K8	Air kerma - brachytherapy
BIPM.RI(I)-K9	Absorbed dose to water – medium energy X-rays
BIPM.RI(II)-K1	Activity of gamma-ray emitting radionuclides
BIPM.RI(II)-K4	Activity of short-lived gamma-ray emitting radionuclides

2. 'In progress' means that the measurements have been carried out and the report is in progress.