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SSDL Newsletter

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From the Editor

This Newsletter celebrates the 150 years of the Metre Convention with articles written by members of the IAEA/WHO SSDL Network. The theme for the 2025 World Metrology Day being 'Measurements for all times, for all people'. SSDLs play a crucial role in linking the user community and the international measurement system. The invited article titled 'The History of the Metre Convention' is written by Massimo Pinto.

A team of experts met to revise the SSDL Charter which governs the activities of the IAEA/WHO SSDL Network. During their discussions, an article was written which is now published in this Newsletter on the value of maintaining a vital quality management system

FIG.1 Experts and IAEA staff during the meeting to review the SSDL Charter

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Services provided by the IAEA in DMRP Section

The IAEA's Dosimetry and Medical Radiation Physics Section focuses on services provided to Member States through the IAEA/WHO SSDL Network and on a system of dosimetry quality audits. The measurement standards of Member States are calibrated, free of charge, at the IAEA's Dosimetry Laboratory. The audits are performed through the IAEA/WHO postal dose audit service for SSDLs and radiotherapy centres by using radiophotoluminescence and optically stimulated luminescence dosimeters (RPLDs and OSLDs).

The Dosimetry Laboratory's Quality Management System has been reviewed and accepted by the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB). Some of the IAEA Calibration and Measurement Capabilities (CMCs) are published in Appendix C of the BIPM key comparison database (KCDB).

The IAEA CMCs can be found at the following web site: https://www.bipm.org/kcdb/

The range of services offered by the IAEA's DMRP Section are listed below.

Services	*Radiation quality*
**Calibration of ionization chambers (radiation therapy, brachytherapy*, radiation protection, and diagnostic radiology including mammography)	X rays and γ rays from ^{137}Cs and ^{60}Co beams ^{137}Cs, ^{60}Co, $^{@}$linac photon beams* and ^{192}Ir brachytherapy sources
**Comparison of ionization chamber calibrations coefficients (radiation therapy, radiation protection, and diagnostic radiology including mammography) for SSDLs	X rays and γ rays from ^{137}Cs and ^{60}Co beams
Dosimetry audits (RPLD) for external radiation therapy beams for SSDLs and hospitals	γ rays from ^{60}Co, high energy X ray beams and electron beams
Dosimetry audits (OSLD) for radiation protection for SSDLs	γ rays from ^{137}Cs
Reference irradiations and blind dose checks for dosimetry audit networks (radiotherapy)	^{60}Co, high energy X ray and electron beams
Reference irradiations to dosimeters for radiation protection	X rays and γ rays from ^{137}Cs and ^{60}Co beams
High Dose Rate Brachytherapy audits	^{60}Co and ^{192}Ir

* Calibration services are not included in the IAEA CMCs published in the BIPM KCDB.
** Technical procedures and protocols for calibrations and comparisons are available on our website https://ssdl.iaea.org/
$^{@}$ Service available only for SSDL's that have activities in this area.

Member States interested in these services should contact the IAEA/WHO SSDL Network Secretariat, for further details, at the address provided below. Additional information is also available at the web site: *https://ssdl.iaea.org*

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Note to SSDLs using IAEA calibration and audit services:

1. To ensure continuous improvement in IAEA calibration and audit services, SSDLs are encouraged to submit suggestions for improvements to the Dosimetry Contact Point.

2. Complaints on IAEA services can be addressed to the Dosimetry Contact Point.

3. Feedback can be provided using the form on our website: https://ssdl.iaea.org/

https://iris.iaea.org/public/survey?cdoc=DOL00100

Helen Khoury Legacy

On February 2, 2025, we awoke to overwhelming feelings of sadness, helplessness, and disbelief. Our dear friend Helen, a strong warrior who seemed indestructible to us, suddenly left us, creating a devastating void. Helen was a distinguished medical physicist and radiation metrologist. Her strength and vast knowledge allowed her to navigate not only various areas of medical physics but also other applications of radiation. As a full professor in the Department of Nuclear Energy at the Federal University of Pernambuco, she dedicated herself to sharing her extensive knowledge through research and teaching. Her multidisciplinary skills, unparalleled teaching abilities, and immense work ethic enabled her to conduct research across a diverse range of fields, including nuclear dosimetry and instrumentation, ionizing radiation metrology, semiconductor detectors, luminescent dosimetry, and the application of non-destructive analysis techniques in studies of cultural heritage. With courage and determination, she established the Metrology and Dosimetry Laboratory in Recife, quickly positioning it as one of the best in Latin America. Committed to disseminating nuclear energy knowledge, she created the remarkable Museum of Nuclear Sciences at DEN/UFPE, the first and only nuclear museum in the country.

Helen's immense leadership skills were noteworthy. She led with empathy, winning over everyone with her clear and assertive communication of ideas and objectives. She earned recognition from her peers for her knowledge, honesty, and integrity. She stood out for the energy with which she conducted her projects, constantly innovating and motivating everyone involved. These qualities were appreciated by all, including renowned scientists and both national and international authorities.

Always tireless, she served as president of several scientific societies, participated on the editorial boards of important scientific journals, and contributed to advisory committees. She excelled in her collaborations with the IAEA, coordinating several projects of both national and international significance.

Helen received numerous honors, including the Carneiro Felippe Medal from CNEN in 2019. She was designated an Honorary Member by the Pernambuco Radiology Society, and, in 2022, she was awarded the honorary title of Citizen of Pernambuco by the Legislative Assembly of the State of Pernambuco.

Although her scientific achievements are countless, they never caused her to distance herself from the family she deeply loved and cherished. Anyone fortunate enough to be Helen's friend learned the true meaning of friendship. Time seemed to flow differently

for her, as she always made time her loved ones, remaining an incredible friend, wife, mother, and grandmother.

The passion she had for dosimetry and ensuring quality in measurements led her to various activities through the IAEA Technical Co-operation for the Secondary Standards Dosimetry Laboratories (SSDL) and REPROLAM (Occupational Radiological Protection Optimization Network in Latin America and the Caribbean). In the past few months, she was working on establishing a formal training program for radiation metrologists at her institute. Her dedication for capacity building of SSDL personnel in Latin America region was immense.

May her immense legacy continue to inspire and serve as an example, today and always, to all medical physicists, radiation metrologists, scientists, educators, and all people.

By Simone Kodlulovich Renha

The Value of Maintaining a Vital Quality Management System for SSDLs

Sibusiso Jozela (NMISA), Samia Mohamed (FANR), Massimo Pinto (ENEA-INMRI), Paula Toroi (STUK)

Why a Quality Management System?

Quality management in the regular operations of a Secondary Standards Dosimetry Laboratory (SSDL) are a unique guarantee to its customers: they can be sure that they will receive the service that they are seeking in a fair, transparent, and competent manner. A proper implementation of the Quality Management System (QMS) and recognition of the services would allow any customer to have confidence in their calibration certificate.

Maintaining a vital QMS is an additional, essential element of trust in the operations of an SSDL that would elevate its credibility to the point that goes beyond the calibration service itself.
Establishing an SSDL is a major undertaking that can require an orchestrated effort of scientists, with the support of their government including the country's regulatory body and can take several years [1]. For an SSDL, ISO/IEC 17025 [2] is the most appropriate standard that should be followed towards the establishment and the maintenance of a QMS.

Quality in SSDLs is a crucial aspect as in any other organizations. It can be defined as set of policies, procedures, and practices implemented in the laboratory to ensure consistent quality and accuracy in its operation. This encompasses a comprehensive approach to managing all SSDL aspects including personnel, equipment, calibration methods, and technical data to ensure reliable and valid results. It is also needed to maintain and improve the reliability of calibrations and other laboratory activities. The roles and responsibilities of the personnel and actions leading to potential non-conformance are defined.

Establishing a QMS in an SSDL can provide numerous benefits, such as:

- Consistent Quality: QMS provides an opportunity to enhance and have consistent improvements in its services through following written standard procedures for all activities of SSDL which can reduce the risk of errors and ensure accurate and reliable results. Moreover, it improves the communication and collaboration between personnel and stakeholders through sharing the same vision, mission, and objectives.
- Better Decision Making: The QMS is a live document that empowers all personnel at all levels to take ownership of QMS and contribute to its success. It encourages all SSDL personnel to be involved in reviewing and evaluating the efficiency and effectiveness of Laboratory system. The QMS enables the SSDL to collect and analyse data to have better decision to improve the quality of its service by incorporating Key Performance Indicators (KPIs) to easily assist in identifying area of improvements and action required to address them.
- Compliance with Regulation and Standards: A QMS will ensure compliance with national regulations and up to date best practices from international standard methods. By implementing a QMS, the SSDL can demonstrate its best practice and ease the peer review process through fulfilling the requirements of ISO/IEC 17025 standard.
- Enhanced Risk Management: The QMS assist in identifying and mitigating the risks associated with SSDLs activities and its relationship with its personnel and stakeholders. It also opens for opportunities that seeks for continuous improvements. It is also very important that an SSDL ensures that risks and opportunities associated to its activities are identified, assessed, evaluated and controlled on a continuous basis to ensure that it achieves its objectives, enhances opportunities and prevents and reduces undesired impacts and potential failures in its activities and achieve improvement [2].
- End User's Satisfaction: Implementation of QMS will help in understanding and meeting end users' needs and expectations. Collection and data analysis of end users' feedback can identify gaps and areas for improvements which can lead to more opportunities to enhance services.

Reviewing regularly: who can do it?

In compliance with the ISO/IEC 17025 standard, the SSDL should not limit itself to writing the QMS documentation: the SSDL needs to verify and show appropriate and sufficient implementation through an audit process either in the framework of a peer-review project, e.g. through the TC-Q projects of the Regional Metrology Organisation (RMO) to which the SSDL belongs or with the assistance of an accreditation body. In either case, however, it is of utmost importance that the assessment is conducted by experts who have a demonstrated competence in the area of operativity of the SSDL whose QMS is being verified.

Peer reviewers involved should be independent, have the necessary experience, and be suitably qualified to conduct the review, as both CIPM MRA and ISO/IEC documentation state [3, 4]. An external, independent peer review should in no case be substituted by an internal review where the independence of the experts cannot be fulfilled. However, it is also well recognized that regular internal reviews are a valuable instrument towards the consolidation of a QMS and in preparation of the evaluation by external, independent experts. The SSDL shall conduct internal audits at planned intervals to provide information on whether the management system conforms to the laboratory's own requirements for its management system, including the laboratory's activities and the requirements of this document, are effectively implemented and maintained. The internal audits shall be carried out by competent, trained and qualified personnel. The laboratory management shall review its management system at planned intervals, in order to ensure its continuing suitability, adequacy and effectiveness, including on the stated policies and objectives related to the fulfilment of this document.

References

1. IAEA Human Health Series 44: Establishing a Secondary Standards Dosimetry Laboratory (2023).
2. ISO/IEC 17025, General Requirements for the Competence of Testing and Calibration Laboratories (2017).
3. CIPM-MRA G12, Quality management systems in the CIPM MRA, version 1.0, (2021)
4. ISO/IEC 17011: Conformity assessment - Requirements for accreditation bodies accrediting conformity assessment bodies (2017)

*The History of the Metre Convention

Massimo Pinto, Italian National Institute of Metrology of Ionizing Radiation, ENEA-INMRI, Italy

Imagine living in a world where you wish to prepare a calibration certificate for a customer, in which the quantity of interest is absorbed dose to water, but you cannot express it in grays because your customer lives in a country where gray is not the unit of absorbed dose to water. Would you still use gray but add a courtesy note to assist your customer in the translation to their units? This may sound way like a far off reality, but such a world actually did exist, and not so long ago. Let's travel 150 years back in time.

The Metre Convention

The Metre Convention is an international treaty that was signed by 17 countries in Versailles on May 20, 1875. Almost a century and a half later, it is difficult to imagine our globalized society, founded on international cooperation between countries of every continent, trade, industrial production, and international scientific collaboration, without the signing of the Metre Convention. In the book "*History of Measurements in Society since 1875*", that is, precisely from the year the treaty was signed, the author Sergio Sartori [Sartori], writes that:

"Citizens of industrialized countries perform, or have others perform for their needs, on average, several dozen measurements per day"

Measuring, therefore, concerns us all, even if we barely notice it, taking measurement somewhat for granted and assigning it at most a background role in our daily lives. In the original documents of that day in May in Versailles, written in an era when French was the official language of diplomacy, and which had replaced Latin even in the language of science, it is written that the actions agreed upon by the countries that signed the Metre Convention were essentially three:

1. The establishment of a *Bureau*, something halfway between an *Office* and an *Institute*, which would be responsible for maintaining international cooperation between the governments that had met in Versailles and any others that had signed the Convention in the following years. The headquarters of this *Bureau* would be assigned shortly by the French Government.
2. An international political body was established, the General Conference on Weights and Measures (CGPM), formed by the delegates of the signatory governments, which would meet every four years to examine the actions necessary for the propagation of the units of measurement in the world.
3. A scientific body was established, the International Committee for Weights and Measures (CIPM). This too would meet every four years with the aim of promoting the international uniformity of units of measurement and would advise the Governments in making decisions through the General Conference itself. The Council would also have the task of supervising and directing the *Bureau*.

Despite the evolutions this scientific-diplomatic body has seen over time, the organization that the Convention's signatory countries gave themselves in 1875 has remained substantially the same for well over a century. This demonstrates how strong the foundations laid by the Convention were. The *Bureau International des Poids et Mesures* (BIPM) is still there, although with tasks that have expanded over time, on a hill on the left bank of the Seine in the Parc de Saint Cloud in Sèvres, which was once a royal hunting reserve. To house the *Bureau*, a building was recovered, the Pavillon de Breteuil, which had already been used for some of King Louis XIV's festivities.

The foundations of the metric system: The French Revolution

To understand why this international agreement was reached only towards the end of the 19th century, why it was in Versailles, and why it was called the Metre Convention, we must first turn the clocks back just over 80 years and immerse ourselves in the midst of the French Revolution.

We remain in the vicinity of Paris, namely the Paris meridian, because it is along this meridian that a part of this story unfolds. The ‘emotional temperature’ of the months following the storming of the Bastille and in the early years of the Revolution was, as is known, characterized by the desire for dignity and equality of all people on Earth. However, this was a transversal desire for equality, which also had very practical aspects, without thereby diminishing the values of the Revolution. Among the origins of inequalities between social classes was also the power of the nobles to establish the value of the units of measurement in force on their properties. For harvest weights and land dimensions, there were many units with different names - each with dozens of variations according to the territory and none equal to another. The tax that had to be paid depended on the measurement of the extent of agricultural land, and the nobles secretly modified the units of measurement to raise funds through tax increases. The situation was no longer tolerable. With inconveniences extended to trade, anyone who wanted to exchange goods in foreign territories would always have to carry "comparison tables" with them while conversion tables were complex and often incomplete. In international relations, the situation was so complicated that cartographers always had to indicate the respective scales adopted on maps, and this risked generating errors. Speaking of these errors, the quote attributed to Louis XIV is famous:

"My cartographers have stolen more land from me than my enemies"

The people therefore strongly suspected that the nobles were making fun of them, and popular discontent was setting the stage for revolt. Tired of this arrogance, the people essentially demanded standardization: that it be possible to fix these units in time and that these units be the same in all the lands of France, for more transparent taxes and for fairer trade. Even the King's units, or other units, would have been fine, if they were the same, uniformly, throughout France. These are very similar prerequisites to what inspired the European common market and, in even more recent times, the monetary union. Understandably, the nobles were very reluctant to lose the control they exercised over taxes. Considering the power the Nobility had, no king of France had ever managed to unify weights and measures., The feudal age had destroyed whatever uniformity there had been after the Roman Empire and after Charlemagne. Supported by scientists and thanks to a delicate and rare partnership between men of science and politicians, the people obtained much more than the standardization of units of measurement - they obtained *universality*, as we shall see shortly. In the book *The Measure of the World*, the French writer of Algerian origin Denis Guedj tells us about a young artillery lieutenant, Claude Antoin Prieur-Duvernois, a member of the Dijon Academy of Sciences; Charles Maurice de Talleyrand a deputy of the Clergy, and the Marquis de Condorcet - a trio that would be of capital importance in onset of the metrological epic [Guedj]. Referring to what could inspire one of the new units of measurement, Lieutenant Prieur-Duvernois mentioned:

"...by choosing an arbitrary standard, whatever precautions are taken to preserve it could not securely protect it from all possible accidents, nor from the slow alteration to which every body is subject "

Put differently, the arbitrary is ephemeral.

Furthermore, towards a standardized system, so-called reduced in units of measurement, in which there would be far fewer, Deputy Talleyrand said, in solemn words:

"When a Nation prepares to undertake a great reform, it must avoid, it must even fear, doing it partially, so as not to be forced to return to it, and if it is a reform of weights and measures, it is not enough to reduce it to a single weight, to a single measure, as could easily be done by resorting to the King's measures. The solution to the problem must be ***perfect****, this reduction must relate to an* ***invariable model taken from nature****, so that all Nations can resort to it in case the standards they have adopted should be lost or end up being altered."*

A perfect measure. An invariable model, taken from nature. Here the idea takes shape that the new units of measurement will no longer be local and ephemeral; rather, they will be universal and eternal. If we take as a starting point the progress achieved in the field of mechanics and geodesy, the imagination of the time could only rely on two phenomena that could serve as the basis for a universal measure: the movement of the pendulum and the Earth.

A pendulum is made of a thread, fixed for example to the ceiling, and a mass suspended from this thread. It completes a full oscillation in a period of time, which depends only on the length of the thread and not, as one might think relying on intuition, on the value of the mass. Pendulums with equal thread lengths notably oscillate with the same period - a property known as isochronism. From the measurement of the second, one would have gone back to the 'length' of a second, determined as the length of the pendulum's thread whose oscillation is completed in just one second. What a fantastic connection between time and length! But the pendulum's candidacy for the universal unit of length failed, because it was observed that the pendulum in Paris oscillated more slowly near the Equator. In general, in keeping its length fixed, the oscillation period of a pendulum varied with latitude. The acceleration of gravity gets in the way, and this is not constant over the entire surface of the Earth. The metre could have been defined as the length of the second only at a given latitude (Paris!), but this was not considered as sufficiently universal.

Could the Earth's dimensions offer anything more universal? Discarding the radius and the length of the Equator (too much sea water down there and too many difficult-to-reach countries), it was chosen to define the unit of length starting from the length of the Earth's Meridian, and the choice fell on the one that passes through Paris. But measuring it entirely would have been impossible and a portion of it had to be chosen. So as not to give the impression that the new universal unit of measurement was only French, it was decided that a measurement should be made of the arc of the Paris meridian, the 'Meridian Line', included between Dunkirk in the north of France and Barcelona in Catalonia, down south. It was very important that both the starting and ending points were at sea level. A part of this arc of the meridian in French territory had already been measured more than once. But with much more precise instruments available, it now had to be measured again. The Academy of Sciences proposed it to the Deputies who voted on the decree on March 26, 1791. Four days later, King Louis XVI gave his approval (and funding). A few months later, the King fled.

The challenge was taken up by the French astronomers Pierre Méchain and Jean Baptiste Delambre, and by a physicist, a naval officer, the Chevalier de Borda, who had constructed the 'repeating circle', an instrument that would allow much more accurate measurements than those already available (precise, portable, better than the English variants). The undertaking was far from simple, and the obstacles to overcome were numerous, both technical and political, including prison and the guillotine for some of the members of the CIPM, established shortly before the start of this challenge. From the measurement of the arc of the meridian between Dunkirk and Barcelona, the quarter of the meridian between the Pole and the Equator was estimated, and dividing this length by 10,000,000, the length of the *metre* was obtained. It was a very accurate measurement and very close to the current value. Today we would say that the two measurements, that of Méchain and Delambre and the current one, are in agreement within two parts in 10,000. on the distance between *Piazza del Campidoglio* in Rome and *Piazza del Duomo* in Milan, there would be a difference between the two measurements of only…96 metres! This is incredible if one also considers that Méchain and Delambre carried out these measurements traversing hills and positioning signals in makeshift locations, often under the distrustful eyes of the locals.

Once completed, it was clear that such an undertaking would not be carried out again. To make the new unit of measurement practical to use, it was therefore necessary to resort to an artifact, although on this occasion this artifact was dictated by a measurement of the Earth. Thus, in 1799, a *metre* was forged in platinum, which would later become the 'Metre of the Archives'. Some copies of this metre would be made in marble and displayed at human height on the facades of some palaces so that everyone would have access to them. Walking through the streets of Paris, two can still be found: one at number 36 rue de Vaugirard and the other at number 13 place Vendôme. The *kilogram* was also derived from the metre, defining it as the mass of a volume of distilled water that filled a cube with a side equal to one decimetre, or one-tenth of a metre (10 cm). This definition proved to be very precarious. But nevertheless, with the foundations of a universal system of measurement having been laid, it was only necessary to agree on the names for the new units of mass and length. Using the old names was out of the question. Once again, thinking of a future in which this revolution would also bring advantages to other countries, the French language was abandoned and inspiration was drawn in roughly equal parts from Latin and Greek, so as not to offend anyone. It was a decimal system made up of multiples and submultiples, with the submultiples were taken from Latin (*milli*, *centi*, and *deci*) while the multiples were taken from Greek (*deca*, *hecto*, *kilo*, *myria)*. These defined the seven prefixes. Then there were the roots: *ara* was taken from the Latin *area*, 'surface'; *litre* was taken from the Greek *lítra*, which was the measure of liquids for the Greeks. The Greek, *grámma*, which means 'scruple' and was the unit of weight of the Romans, inspired the name of the root *grammo* (gram) and the root *solid* was derived from the Greek *stereós*. With seven prefixes and five roots, the nomenclature was settled. The last root was still missing: 'metre' was proposed by August Savinien Leblond. A simple word, which even he could not have imagined would become:

"The seed of an entire family of Greek words, and of hybrid words, crosses of Latin and Greek"

Making this nomenclature acceptable to the population was not at all easy. Combining prefixes and roots resulted in words never heard before by anyone! Denis Guedj quotes Article 5 of the new Constitution that regulates the dimensions of the cantons:

" There shall not be more than one myriametre of distance between the most distant Commune and the capital of the Canton."

The metric-decimal mania did not spare the measurement of time. Clocks were made with a dial divided into 10 hours, in which there were 100 minutes and in each of these 100 seconds. Some of these can still be seen in the *Musée des Arts et Métiers* in Paris.

Across the Channel: The English

France was not the only country to have thought about the reduction of units of measurement. Indeed, it was preceded by very little by the English House of Commons, where Sir John Riggs Miller had spoken on July 25, 1789, requesting that the new (English) standard of length:

"... derive from something invariable and immutable, taken from nature, which is always equal and the same at all times and in all places"

The formula was the same one. Denis Guedj recounts that Talleyrand looked very favourably on an agreement with England, with which France already felt strongly linked both scientifically and politically. There was collaboration to be done in nautical cartography, and it was no longer possible to continue with stretches of sea and coast mapped with a myriad of different units of measurement. Sir John Riggs Miller was not elected for a second term to the House of Commons, and the dream of the English metric system floundered. Who knows what England would be like today, with its miles, inches, feet, fluid ounces, and pounds, had the collaboration between Talleyrand and Sir John Riggs Miller continued.

Forward to 1875

After France, the Netherlands also adopted the standardization of units of measurement in 1820. And what about the other peoples? The nineteenth century was an era of great industrial expansion, but also of wars such as the American Civil War or the Franco-Prussian War. In general, hostilities between countries had intensified as did nationalism. Even non-national states were in crisis (Prussia, the Ottoman Empire) and this did not contribute to creating a stable condition for international cooperation. The reason more than 80 years passed to arrive at the Metre Convention is dictated more by necessity: the climate of depression that enveloped Europe. Like many other treaties of that period, the Metre Convention was an effort aimed at solving the complex problems posed by the recession and therefore did not arise from the enlightened premises of the French Revolution: science was not put at the centre. In those years, new forms of international cooperation had to be envisioned. Sergio Sartori writes that:

" A network of organizations and treaties was formed that opposed a technical, legal, and administrative internationalism to the nationalism and political egoism of individual States "

The Metre Convention was written according to the needs of agriculture and commerce. Nothing to do with the glorious ambitions of universality of the units of measurement of the Academy of Sciences. And yet, without these practical needs, the world today would be very different. It is thanks to the decision to use the same units of measurement for length that the parts of an engine made in multiple factories, in multiple countries around the world, fit together – making the engine as functional as it is durable. It is thanks to the uniformity of the units of measurement of electric current, resistance, and capacitance that different parts of a computer or a mobile phone, made in different parts of the world, when put together, couple properly. (At least, without exploding!)

The Metre Convention is practically everywhere, every day, even if silently. With the Metre Convention, the international prototype of the kilogram, the unit of measurement for mass, forged: it was a small cylinder made of a platinum and iridium alloy that will be kept under three glass bells in a safe house in the *Bureau* in Sèvres, which can only be opened by inserting three keys, kept by three different people and who are brought together only for a periodic inspection of the prototype. It will be the unit of measurement for mass for 145 years. Safeguarding it will be one of the tasks assigned to the *Bureau*.

The 26th CGPM and the new SI

The 26th General Conference on Weights and Measures, the political body that was established with the Metre Convention, met in Versailles on October 16, 2018. It was a quite different meeting from the previous ones, and special because part of the proceedings were open to the public, to journalists from all over the globe, as well as scientists including the two Nobel laureates Klaus Von Klitzing and William Phillips. At that General Conference, the signatory governments of the Convention (no longer the 17 countries of 1875 but 59, as of 2018, in addition to another 42 that have 'Associate' status) unanimously voted, through their representatives, for a resolution adopting the new International System of Units, which would come into force in on May 20, 2019, to honour the day on which the Metre Convention was signed by the first 17 countries. With the new International System of Units, the units of measurement of all seven fundamental quantities are defined based on universal physical constants. The last artifact, the one that, by definition, constituted the unit of measurement for mass—the international prototype of the kilogram—is also sent to the "attic" [Quinn].

The retirement of the international prototype of the kilogram was also a long process, made up of numerous conferences and extremely accurate measurements based on extensive international cooperation. Part of this story is narrated in the Norwegian film by director Bent Hamer, titled "1001 Grams" [Hamer]. The protagonist Marie, a metrologist from the Norwegian Metrology Institute, travels to Paris several times to verify the Norwegian national kilogram standard and to participate in the transition to the new definition of the kilogram based on the Planck constant. The film also very delicately describes the unease that researchers, particularly Marie's father who worked in the same institute as his daughter, feel in abandoning a tangible object – the last of the artifacts – to move to a unit that, although universal and reproducible everywhere, appears much less tangible.

With the new International System of Units, a page was turned on a history lasting millennia from Ancient Egypt and the Assyrians, from Mesopotamia – a history in which the units of measurement of physical quantities were made with artifacts, starting from the cubit of the Pharaoh or the arm; passing through the Metre of the Archives, the one made in 1799 at the end of the undertaking by Méchain and Delambre; up to the last one, the international prototype of the kilogram. With all artifacts archived, we move on to atoms, to nature, to universal physical constants, to modern science. Albert Einstein, Max Planck, and Ludwig Boltzmann – their names are found in some of the physical constants that form the basis of the new International System of Units. This is the greatest revolution in the science of measurement since the time of the French Revolution.

À tout le temps, à tout le peuple

It seems then that the dream of Méchain, Delambre, Lagrange, and the scientists of the French Academy is realized: units of measurement are made accessible to all and for eternity, *à tout le temps, à tout le peuple* (to all time, to all people).

In the era of space exploration in which probes are sent beyond the solar system in search of intelligent life forms, this adds a touch of humility to our civilization: we will be able to describe ourselves and our planet Earth by referring to universal physical constants. We no longer have to use to artifacts that only make sense on our Planet –a cubit, an arc of the Earth's meridian, a platinum-iridium prototype –and that would be unknown elsewhere. If, in introducing ourselves to a distant civilization, we were to start a discussion based on our units of measurement, we would truly make a bad impression. That would be a cosmic blunder.

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*This story was also narrated, in Italian, in the Italian national public RAI radio programme “Wikiradio” on May 20, 2019:

https://www.raiplaysound.it/audio/2019/05/WIKIRADIO---La-Convenzione-del-Metro--ba563aef-e71c-4e3f-a48c-cd7cb287901a.html.

The IAEA's Role in *Measurements for All times for All people*

Dunja Stojanovic, Dosimetry and Medical Radiation Physics Section, IAEA

In 1976, the IAEA and the World Health Organization (WHO) jointly launched the international Secondary Standards Dosimetry Laboratory (SSDL) Network –a global initiative aimed at enhancing the accuracy and consistency of radiation dose measurements worldwide. This effort was particularly crucial for countries lacking access to Primary Standards Dosimetry Laboratories (PSDLs) or formal integration into the international metrology system [1].

The primary goal of the SSDL Network is to ensure that radiation dosimetry performed by end-users remains traceable to internationally recognized standards. At the centre of this Network is the IAEA Dosimetry Laboratory (DOL) which acts as a reference point for the entire system. DOL provides a wide range of services to support traceability and radiation measurement accuracy across the globe through the calibration of dosimetry equipment, reference irradiations, inter-laboratory comparison programmes, and audit services for Member States [2].

DOL ensures accurate and consistent radiation measurements by maintaining and calibrating national reference standards used in radiation therapy, radiation protection, and diagnostic radiology. In support of this, the IAEA offers periodic calibration of ionization chambers and electrometers. It also provides reference irradiations for passive dosimeters, helping national labs maintain reliable personnel monitoring systems with all services traceable to primary standards [2].

The laboratory operates under a comprehensive Quality Management System (QMS) in line with the ISO/IEC 17025 requirements that is regularly peer-reviewed by independent experts. This system helps maintain transparency and quality, reinforcing the trust of national laboratories in the calibrations provided by the IAEA [2].

Since 1976, the IAEA has maintained a register of dosimetry laboratories that are part of the IAEA/WHO SSDL Network. The Network has steadily grown over the years and now proudly includes 89 member laboratories, 18 affiliated members, and 5 collaborating organizations committed to advancing global dosimetry standards.

Calibrations

Calibration procedures for radiotherapy, diagnostic radiology, radiation protection, and brachytherapy are tailored to the specific requirements of each application but share the common goal of ensuring accuracy and traceability to international standards.

At DOL, reference ionization chambers in radiotherapy are calibrated in terms of air kerma for Co-60 gamma radiation and low- and medium-energy X ray beams as well as in terms of absorbed dose to water for high-energy photon beams and Co-60 radiation. For diagnostic radiology, calibrations are performed for diagnostic and interventional radiology beams following the procedures outlined in IAEA TRS-457 [3] and the associated physics fundamental in Diagnostic Radiology Physics Handbook [4], using the substitution method with a monitor chamber to normalize the X ray beam output. Radiation protection calibrations are similarly conducted for Co-60 and Cs-137 gamma radiation as well as ISO 4037 narrow-spectrum X rays, with beam normalization through a monitor chamber for X ray fields.

In brachytherapy, calibrations focus on well-type ionization chambers, establishing reference air kerma rates for low-dose-rate (Cs-137) and high-dose-rate (Co-60 and Ir-192) sources. To maintain consistency and traceability to international standards, the IAEA recalibrates its reference standards every three years at the BIPM or another recognized PSDL.

The air kerma calibration coefficient (N_K) is determined as the ratio of the air kerma rate measured by the IAEA reference standard to the dosimeter reading. The same methodology is applied for the determination of the absorbed dose to water calibration coefficient ($N_{D,w}$).

The calibration coefficients for ionization chambers are defined at the reference point, considered to be the geometrical center of the collecting volume as outlined by the chamber's external walls, unless specified otherwise. These coefficients are linked to standard ambient conditions — a temperature of 20 °C, an air pressure of 101.325 kPa, and 50% relative humidity.

At DOL, calibration coefficients are corrected for influence quantities and reference conditions, with ambient conditions continuously monitored throughout the calibration process to ensure accuracy in the latter.

Calibrations are performed either for a full system —comprising an ionization chamber and an electrometer— or for the ionization chamber alone. For component calibrations, ionization currents are measured using IAEA reference electrometers.

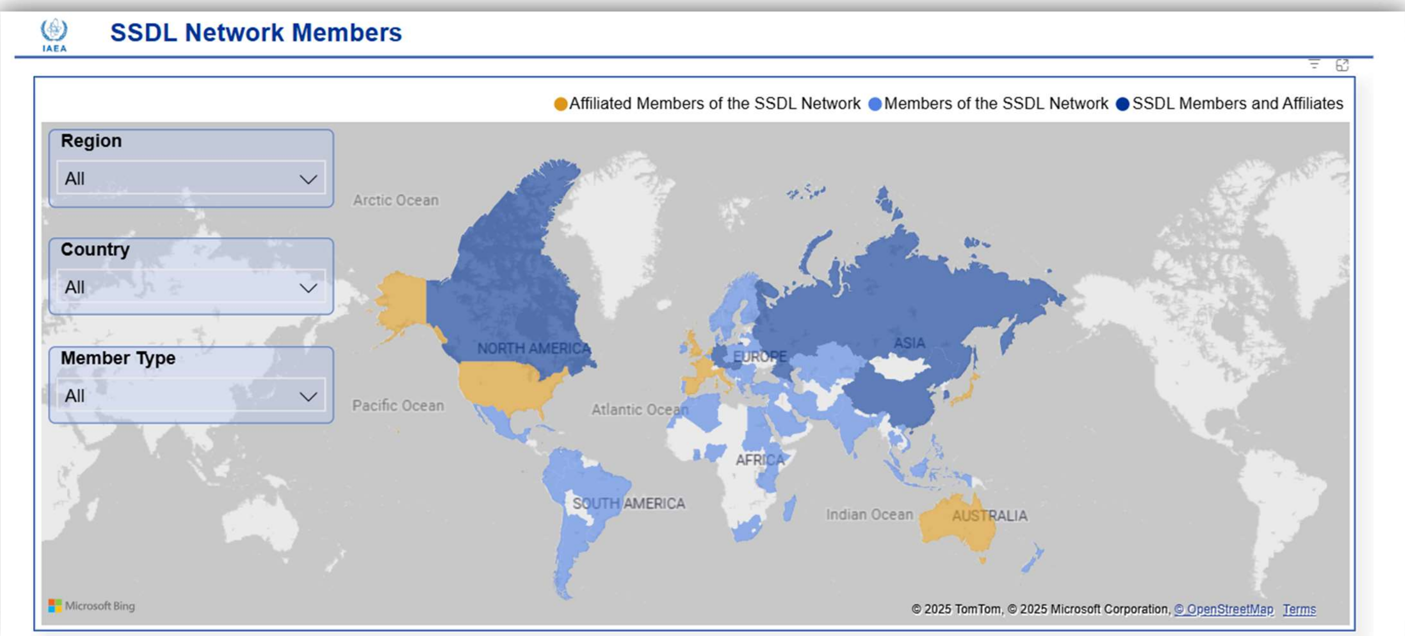

Fig 1. Mapping of the IAEA/WHO SSDL Network members [2].

The bar chart in Figure 2 presents the calibration workload at DOL from 2011 to 2025, distinguishing between the number of calibration certificates issued (blue bars) and the number of calibration coefficients certified (orange bars) each year. Across the years, the number of calibration coefficients certified is consistently higher than the number of certificates issued, reflecting that each calibration certificate includes multiple certified coefficients.

number of certificates issued remained relatively stable, typically between 90 and 130 certificates annually. These trends highlight DOL's resilience and consistent commitment to maintaining the accuracy and traceability in radiation dosimetry and supporting Member States' calibration needs across various periods of operational challenges.

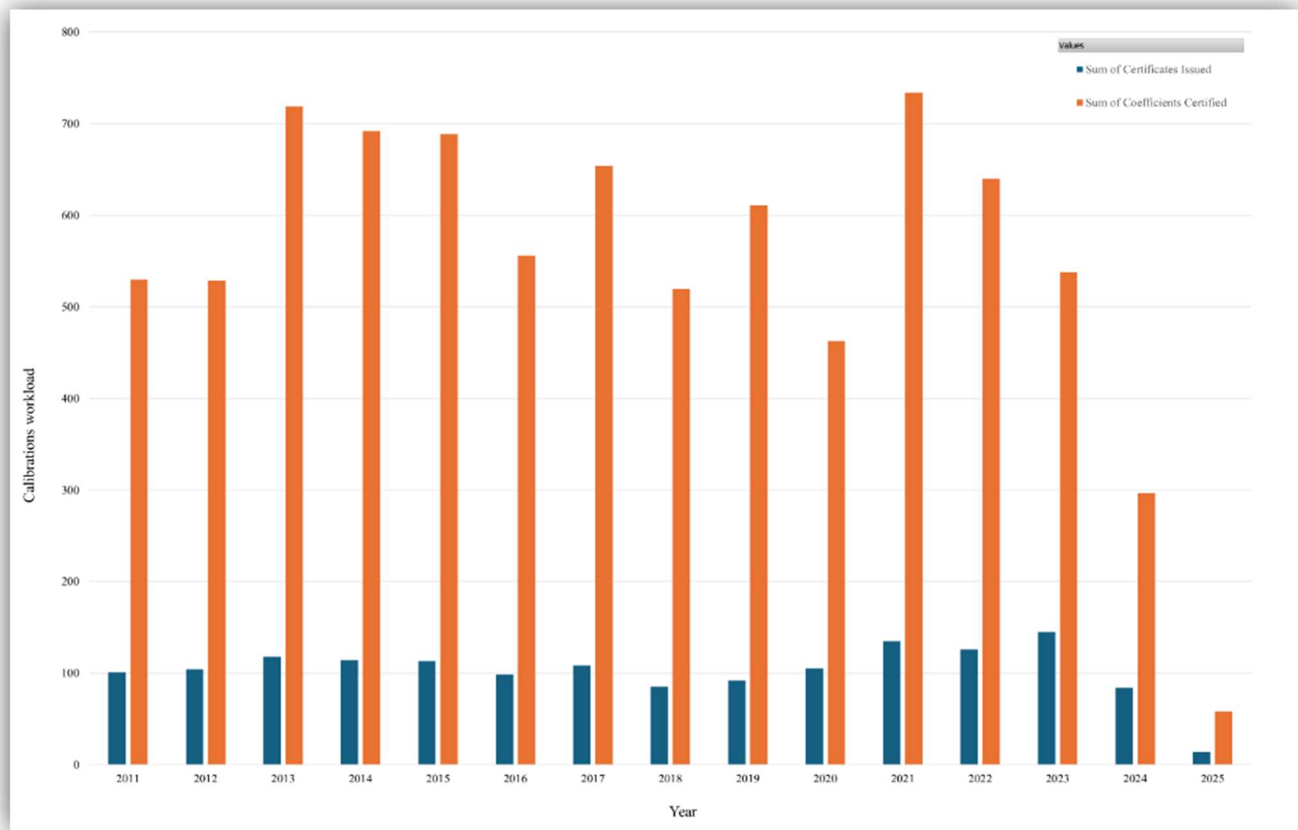

Fig 2. Bar charts showing the calibrations workload at IAEA-DOL from 2011 to 2025, based on data from the SSDL database.

The calibration workload between 2011 and 2023 demonstrates sustained high activity at DOL. From 2011 to 2015, the number of coefficients certified remained relatively stable, with notable peaks in 2013 to 2015. Another peak was observed in 2021, reaching over 700 certified coefficients, demonstrating a strong recovery following a temporary dip in 2020, likely linked to the operational impacts of the COVID-19 pandemic. Throughout the period of the last 10 years, the

Comparisons

The IAEA/WHO SSDL Network offers direct bilateral comparisons with IAEA standards, enabling members to verify the consistency of their national standards and validate calibration procedures at their SSDLs. Comparison programmes are available for radiation therapy, radiation protection, and diagnostic radiology, with defined acceptance limits. As part of these activities, calibrated IAEA ionization chambers are sent to participating laboratories for calibration using their own procedures. The IAEA evaluates the results, issues a confidential report, and, if a calibration coefficient falls outside the acceptance limits, offers support to help resolve any discrepancies.

Dose-Audits

The DOL also supports the Network by providing the radiation dosimetry audit services. In the audit process, participating SSDLs receive a passive dosimeter to be irradiated under reference conditions—at a specified air kerma for radiation protection audits or absorbed dose to water for radiation therapy audits. The irradiated dosimeters are then returned to the IAEA for evaluation. Following the assessment, a confidential report is issued, along with scientific support to address any discrepancies if needed. More about the Luminescent Dosimeters used for Postal Dosimetry Audits can be read in the next article on the page 17.

Networking

Members of the SSDL Network can obtain technical support, training and guidance through the IAEA, helping their staff build expertise in measurement procedures relevant to their responsibilities. Additionally, the IAEA's technical cooperation programme (TCP) has also played an important role over time in establishment of many SSDLs now part of the Network, offering practical training through scientific visits, fellowships, interregional or regional training courses, depending on the priorities and resources. Networking, communication and collaboration are fundamental part of the improvement sharing knowledge worldwide. Therefore, further opportunities for advancement are offered through participation in IAEA Coordinated Research Projects (CRPs), which promote the development and dissemination of new knowledge in radiation metrology, dosimetry, and medical physics, including initiatives such as the updating of dosimetry codes of practice [1].

Measurements for All times for All people

Marking the 150th anniversary of the Metre Convention and reflecting on the IAEA's longstanding role in radiation metrology, the IAEA/WHO SSDL Network highlights the achievements made through international collaboration with all people who are and have been part of the Network, since its establishment. Through a structured framework supported by technical and scientifical assistance, training, comparisons, and collaborative research, the IAEA enables national laboratories to align with global best practices and strengthen the reliability of measurements. Over the years, it has established itself as a vital platform for building trust in radiation measurements, fostering international collaboration while promoting high-quality radiation safety and medical applications across the world – a mission it continues to uphold.

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Luminescent Dosimeters: A Key Tool for Postal Dosimetry Audits

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Radiotherapy is a crucial part of cancer treatment, with approximately 50% of all patients requiring it. To ensure the effectiveness and safety of radiotherapy, a comprehensive quality assurance system is essential. Independent dosimetry audits play a key role as part of a robust quality assurance program to assess the accuracy and reliability of the radiation dose delivered to patients. Postal dosimetry audits have emerged as a valuable tool for conducting such audits ensuring the accuracy of the dose delivered. In addition, at a radioprotection level, remote audits offer an independent verification that ensures the quality, consistency, and traceability of measurements conducted by Secondary Standard Dosimetry Laboratories (SSDL).

Luminescent dosimeters (LD) play an indispensable role in remote dosimetry audits in radiotherapy and radiation protection [1-5]. Their utility stems from favourable dosimetric properties including high sensitivity, accuracy, wide dose range, stability, spatial resolution, compactness, cost-effectiveness, and reusability. LD operate on the principle of energy absorption by lattice defects or dopant traps within crystalline or glass materials. Exposure to ionizing radiation generates electron-hole pairs, which are captured at metastable defect sites. Subsequent stimulation by thermal methods in thermoluminescent dosimeters (TLD), optical methods in optically stimulated luminescent dosimeters (OSLD), or ultraviolet light in radiophotoluminescent dosimeters (RPLD) releases the trapped charge carriers, leading to photon emission (Fig 1). The integrated intensity of luminescence correlates to absorbed dose, enabling quantification via photomultiplier-based readout systems.

To accurately determine the radiation dose from the dosimeter signal, each LD system must be calibrated, and specific physical characteristics must be taken into consideration. The LD system calibration is performed under user defined reference conditions in a radiation field of specific quality traceable to a primary standards laboratory. Any difference between the dose measurement conditions in an experimental setting and the reference conditions should be corrected, taking into account specific characteristics of the dosimeters in use, which include individual sensitivity correction, where applicable, beam quality, linearity, fading and depletion. The following section briefly summarizes the results of the postal dosimetry audits conducted by the IAEA DOL using LD.

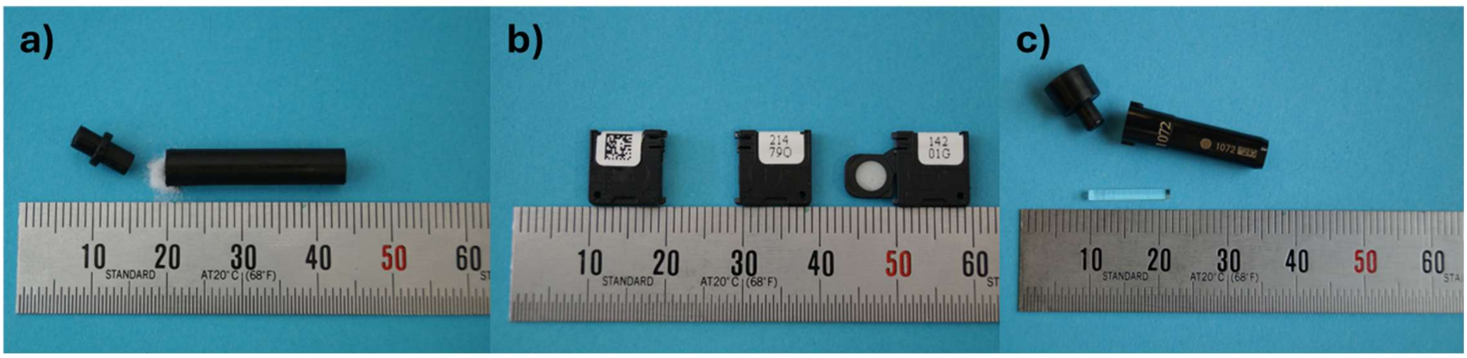

Figure 1. Luminescent dosimeters: a) TL powder (LiF:Mg,Ti, TLD 100), b) OSL (Al2O3:C), and c) RPL (Silver activated Phosphate glass).

For over 48 years, TLDs (LiF:Mg,Ti, TLD 100) have been employed at IAEA/WHO DOL in postal reference dosimetry audits for radiotherapy [4]. The uncertainty associated to this system for radiation therapy beams has been reported as a combined relative standard deviation of 3.2% (k=2) [5], indicating high confidence in the 5% acceptability threshold [1-4]. Between Co-60 and photon beams more than 12,000 certificates were dispatched to radiotherapy centers. The audit results are reported as the ratio of IAEA measured dose to the participant stated dose, D_{ratio}. For TLDs, the historical mean dose ratio for radiotherapy centers was 1.007, with a relative standard deviation of 7.7% (k=1).

Approximately 85% of the certificates fell within the acceptable tolerance range, with an average dose ratio of 1.005 and a standard deviation of 2.1%. In 2016, the final year this dosimeter was in use, 98% of the results were deemed acceptable.

From 1999 to 2013, TLDs were also used to verify air kerma calibrations for radiation protection provided by the SSDLs for Cs-137 and Co-60. The overall relative standard uncertainty for this system has been estimated at 3.4% (k=2) [6]. During this period, 294 for Cs-137 and 16 for Co-60 beams were audited. The mean ratio of the dose measured by the TLD was 1.000, with a standard deviation of 4.3%. About 93% of the audit results fell within the acceptance limits of 7%, with an average of 1.001 and 2.6% standard deviation.

Between 2015 and 2017, the dosimetry audit service enhanced its efficiency by transitioning from TLDs to OSLDs (Al_2O_3:C) for radioprotection [6] and RPLDs (Silver activated Phosphate glass) for radiotherapy [7].

Similar to TLDs, RPLDs are used to audit the beam output of cobalt-60 units and high-energy photon and electron beams. The uncertainty associated to this system for radiotherapy beams has been reported as a combined relative standard deviation of 3.02% (k=2) [5]. Recently, a new reference dosimetry service has been established that combines the use of RPLDs and film dosimetry for High Dose Rate Brachytherapy. Since the introduction of RPLDs, approximately 6,000 certificates have been issued to radiotherapy centers. The mean ratio is 1.001 with a relative standard deviation of 4.8% (k=1). About 95% of the audit results were inside of tolerance with an average of 1.003 and 1.7% standard deviation.

For OSLDs, the uncertainty associated to this system for radioprotection audits has been estimated as a combined relative standard of 3.08% (k=2) [6]. From 2015 until last year, around 180 certificates have been despatched to SSDLs. The mean ratio is 1.003 with a relative standard deviation of 4.1% (k=1). About 97% of the audit results were inside of tolerance with an average of 1.000 and 2.3% standard deviation.

Figure 2 provides an overview of the dosimetry audit coverage to 144 Member States, conducted by the IAEA DOL since the launch of the programme in 1969, extending through the current year.

A key component of the audit services provided by DOL is the monthly dose verification using LDs, which are irradiated at Primary Standard Dosimetry Laboratories (PSDL) and Reference Hospitals (RH) worldwide. For dose verification using RPLDs, figure 3 illustrates the consistency of the average IAEA measured dose to the PSDL or RH stated dose (D_{ratio}) is 1.003, with a standard deviation of 1.3% for a total of 452 irradiated beams, and the corresponding value for air kerma is 1.002, with a standard deviation of 1.7% for a total of 16 Cs-137 sources. These results demonstrate dosimeters system reliability.

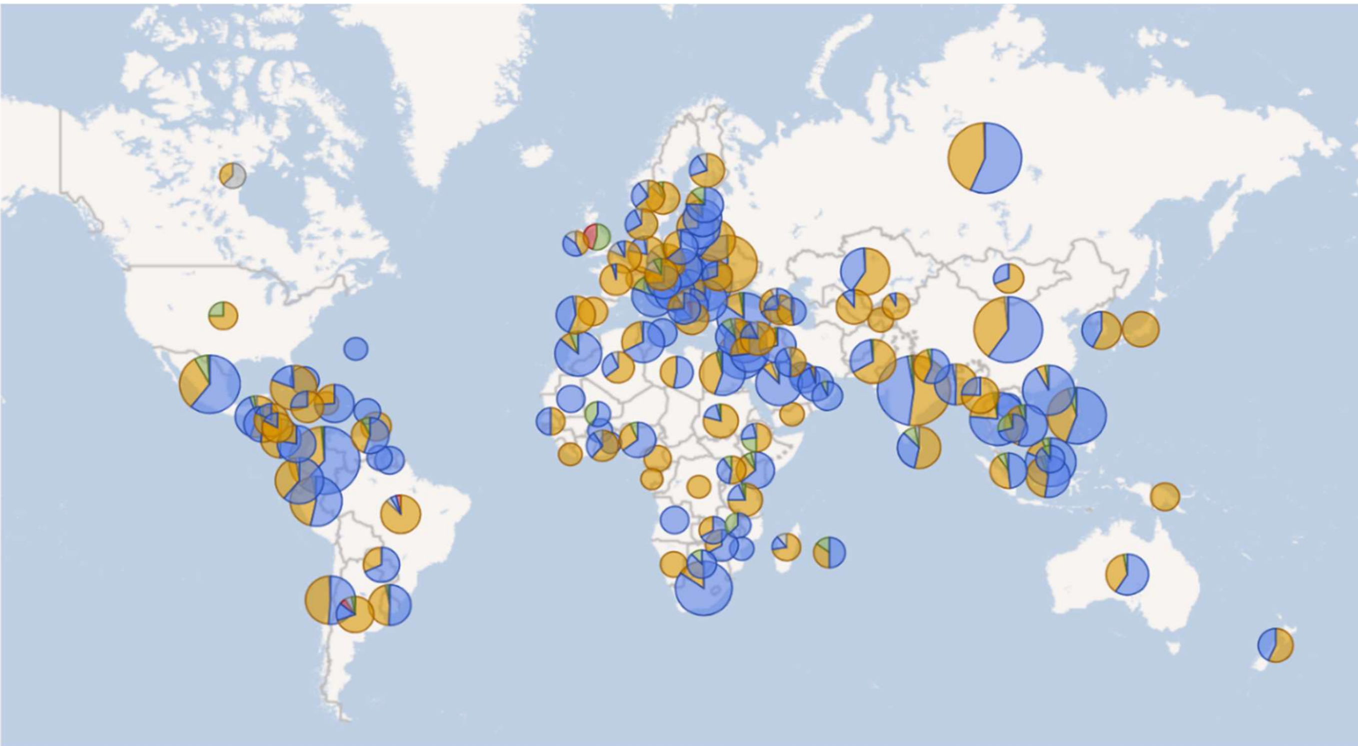

Figure 2. Audit certificates issued by DOL from 1969 to 2025 for various beams, with blue for photons, orange for Cobalt 60, green for electrons, red for brachytherapy, and gray for Cs-137. The size of the spheres represents the relative number of audit certificates.

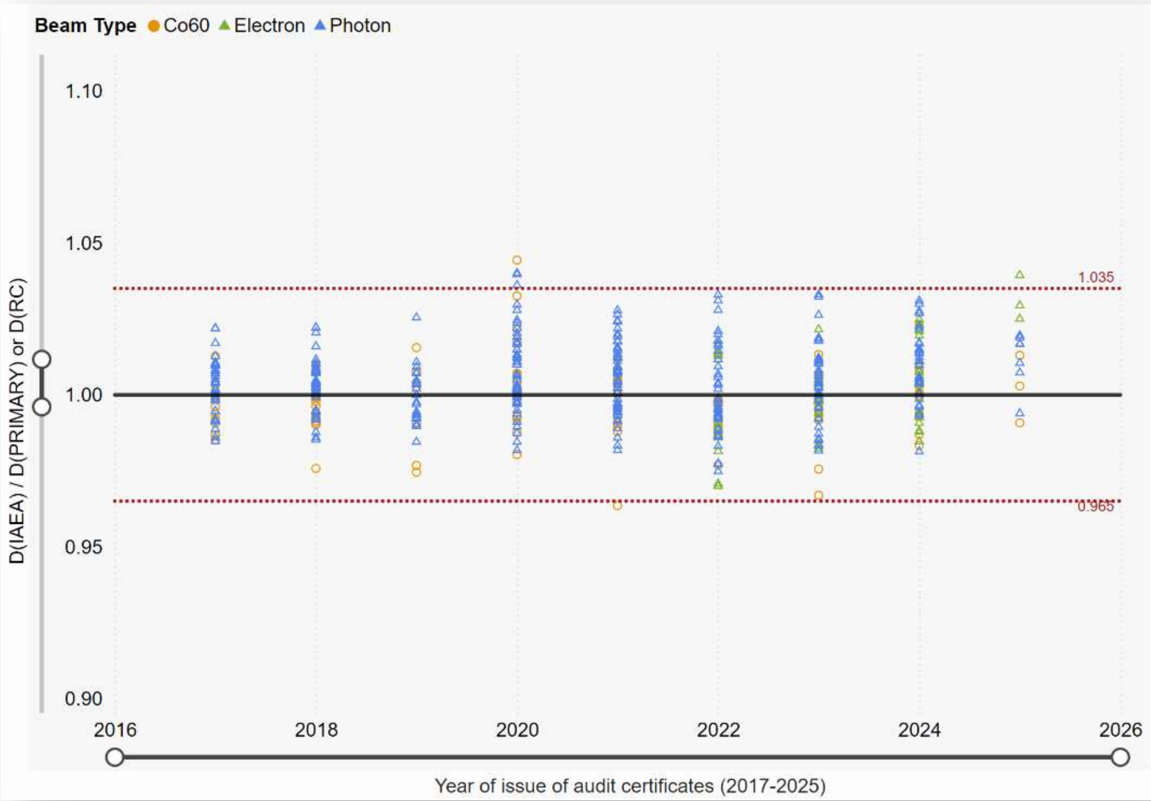

Figure 3. Dose verification of IAEA DOL with respect to PSDLs (PRIMARY) and Reference Hospitals (RC) using Radio Photo Luminescent Dosimeters in radiotherapy during 2017 – 2025.

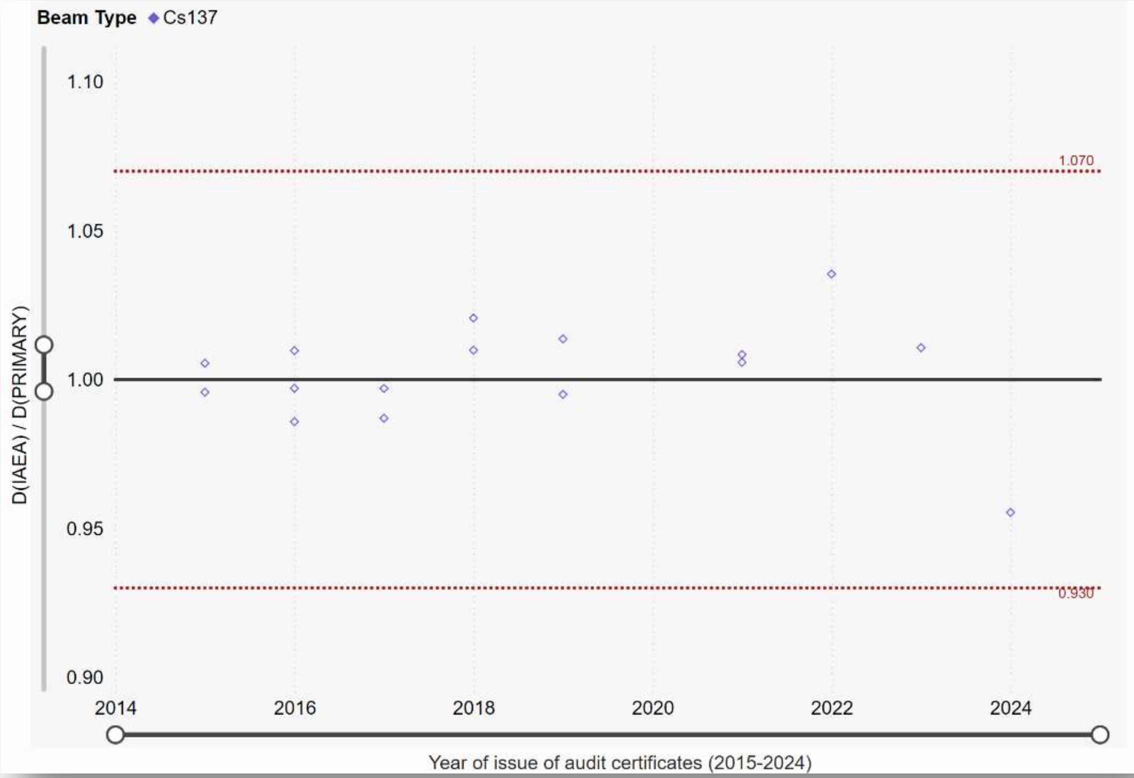

Figure 4. Dose verification of IAEA DOL with respect to PSDLs and Reference Hospitals using Optically Stimulated Luminescent Dosimeters in radiation protection during 2014 – 2025

All dosimetry systems are effective for postal dosimetry auditing, but each requires specific correction factors and handling processes to ensure accurate dose measurement. Handling protocols differ among the three LD systems. OSLD systems are generally user-friendly and do not require special environmental conditions, however, RPLD requires temperature-controlled clean environment to ensure accurate readout. In practice, the routine use of TLD and RPLD systems tend to be cumbersome as compared to OSLDs. However, while TLDs and RPLDs can be reused multiple times without significant loss of sensitivity, OSLDs experience a decrease in sensitivity with accumulated dose, which limits their effective lifespan. Individual sensitivity correction factors play a significant role in LD system calibration. TLDs from the same batch (powder lot) do not require individual sensitivity characterization, whereas OSLDs and RPLDs require individual sensitivity correction factors. TLDs are destructive in the readout, that limits their reuse, in contrast, OSLD and RPLDs allow non-destructive repeated measurements. RPLDs exhibit the slowest loss of stored signal over time after irradiation, followed by OSLDs, while TLDs show the highest rate of signal fading among the three [2,5,6]. Additionally, all three LD exhibit some degree of non-linearity in their dose-response and require energy-dependent correction factors for accurate measurements across different beam qualities. OSLDs and TLDs should be stored in light-tight cabinets to prevent unwanted stimulation, while RPLDs require careful handling to avoid contamination that could impact the signal readout. The reusability of LD, when coupled with appropriate annealing procedures, contributes to long-term cost-effectiveness.

In summary, despite differences in their operational characteristics, all three LD systems are capable of providing accurate measurements in postal dosimetry audits for radiotherapy and radiation protection applications, provided that appropriate system handling and dosimeter processing protocols are followed.

Participation in inter-laboratory comparisons is highly recommended to ensure the reliability and accuracy of dose measurements when using LD systems for postal dosimetry audits.

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Advancements in Monochromatic X-ray Sources at NIM, China

Guo Siming, National Institute of Metrology, China

The National Institute of Metrology (NIM) in China has achieved significant breakthroughs in monochromatic X ray technology, developing facilities that operate across an extensive energy spectrum from 0.218 keV to 301 keV. These innovations provide essential support for high-precision measurements and calibration applications.

A key development is NIM's diffraction-based monochromatic X-ray facility, which delivers outstanding performance in energy accuracy and stability. Operating within the 0.218-301 keV range, this system combines crystal diffraction and grating techniques to generate highly monochromatic X-rays. The facility achieves energy resolution better than 3.0%, with energy stability within 1.0% and flux stability within 2.0% over eight-hour periods. This exceptional precision enables accurate calibration of space-borne X ray detectors and other scientific instruments. The facility has been successfully employed to characterize satellite detectors, assessing energy linearity, resolution, detection efficiency, and temperature response – capabilities that strongly support China's space science and high-energy astrophysics initiatives.

NIM has also developed a tunable monochromatic X ray source covering the 5-40 keV range. This innovation features an ingenious mechanical design based on Bragg diffraction that enables synchronized adjustments of the crystal and X ray tube. This synchronization ensures the output beam remains spatially stable during Bragg angle tuning, substantially improving efficiency calibration accuracy. The tunable source demonstrates excellent performance with precise control over output energy and beam characteristics, fulfilling critical needs in medical and industrial X ray detector calibration while ensuring measurement standard reliability and traceability.

The facilities have already supported calibration for major Chinese satellite projects, including Insight-HXMT (Hard X ray Modulation Telescope): calibrated detectors for energy linearity, resolution, and efficiency in the 20–150 keV range as well as GECAM (Gravitational Wave High-Energy Electromagnetic Counterpart All-Sky Monitor): fine-tuned 67 $LaBr_3$ detectors (6–160) keV, enabling precise absorption edge studies.

Work is ongoing for SVOM, HXI, and GRID missions, ensuring readiness for future launches.

These advancements strengthen X ray metrology infrastructure and contribute to the development of primary X ray standards. By providing reliable, high-precision monochromatic X ray sources, NIM supports applications ranging from fundamental scientific research to practical industrial applications. The facilities also enhance China's participation in international metrology collaborations, promoting global measurement standard unification.

These achievements reflect NIM's dedication to advancing metrology science and technology, fostering innovation, and supporting critical sectors including healthcare, aerospace, and advanced manufacturing. Future research will focus on expanding the energy range, improving source stability, and developing novel applications for monochromatic X rays in emerging scientific and technological fields.

Measurement for All Times, for All People

Reham Hamdy, Ionizing radiation metrology laboratory, National Institute of Standards, Egypt

The history of metrology (the science of measurement) finds one of its earliest and most sophisticated expressions in Ancient Egyptian civilization. Dating back to around 3000 BCE, the Egyptians developed remarkably precise measurement systems that formed the foundation of their advanced society. At the heart of Egyptian metrology was the royal cubit, a standardized length measurement based on the forearm of the king, which was carefully preserved on granite and wooden rods maintained by royal architects. This standardization enabled the incredible precision seen in monuments like the Great Pyramid of Giza, where stone blocks were cut with accuracy to within fractions of a millimetre across great distances.

Egyptian metrological innovations extended beyond length to include sophisticated systems for measuring weight, volume, area, and time. Their weight system utilized the Deben (approximately 91 grams), while volume was measured with standardized vessels for grain, and other commodities. Most remarkably, Egyptian surveyors developed techniques to re-establish land boundaries after annual Nile floods, using geometry and measurement principles that would later influence Greek mathematics. This metrological foundation supported Egypt's complex economy, monumental architecture, and administrative systems for over three millennia, establishing principles of standardization and precision that would influence measurement systems throughout the ancient Mediterranean world and beyond.

The 2025 World Metrology Day theme, "Measurement for all times, for all people," takes on profound significance when applied to the field of ionizing radiation metrology. This emphasizes the critical importance of accurate, reliable, and universally accessible measurements in radiation science, which affects human health, environmental protection, and technological advancement across generations and communities worldwide.

From nuclear energy generation and environmental monitoring to medical diagnostics and cancer treatments, ionizing radiation metrology is essential to many aspects of our lives. In order to ensure the safety and effectiveness of radiation-based technologies and processes, the topic highlights the necessity of standardized measurements that can be relied upon and repeated across time and locations.

When it comes to "all times," ionizing radiation metrology has unique challenges. It must take into consideration how radioactive sources deteriorate over time in order to maintain calibration standards' accuracy and ability to be linked to international references. This temporal aspect is critical in maintaining the reliability of radiation detection instruments and dosimetry systems used in various applications.

The "for all people" component emphasizes how crucial it is to make radiation measurement technologies and knowledge available everywhere. This entails creating affordable and easy-to-use radiation detection devices, encouraging radiation safety education and training while making sure that even areas with limited resources have access to precise radiation measurement capabilities.

This theme serves as a call to action for metrologists, radiation scientists, and policymakers to continue their work towards a future where precise, reliable ionizing radiation measurements are universally available, contributing to a safer and more technologically advanced world for all.

The Ionizing Radiation Metrology Laboratory (IRML) at the National Institute of Standards (NIS) of Egypt serves as the country's primary reference for radiation measurement standards and calibration services.

IRML is tasked with maintaining and developing national standards for ionizing radiation dosimetry, providing essential calibration services for radiation detection instruments used throughout Egypt. IRML conducts research to advance measurement techniques and ensures the accuracy of radiation measurements in medical, industrial, and research applications. The Laboratory plays a crucial role in Egypt's radiation safety infrastructure, supporting radiation therapy centres, diagnostic radiology facilities, radiation protection programs, and industrial applications while ensuring compliance with international metrology standards and practices.

The Italian National Program for the Promotion of Reliability in Measurement of Ionizing Radiation: A Perspective on “Measurements for All Times, for All People”

Alessia Ciccotelli, Andrea Petrucci, Mauro Capone, Aldo Fazio, Luca Carrarelli, Luca Silvi, Marco Capogni, Francesco Tortorici, Pierluigi Carconi, Claudia Silvestri, Gianluca Cappadozzi, Alessia Embriaco, Vanessa De Coste, Alessia Giaffreda, Oriano Bottauscio, and Massimo Pinto

National Institute of Ionizing Radiation Metrology (ENEA-INMRI), Italy
National Metrology Institute of Italy (INRiM), Italy

Over the course of 2021 and 2022, the National Institute of Ionizing Radiation Metrology (ENEA-INMRI) carried out the first National Program for the Promotion of Measurement Reliability in the field of measurements related to the use of ionizing radiation, funded by the Ministry of Economic Development (MiSE, now Ministry of Enterprises and Made in Italy, MIMIT). Six interlaboratory comparisons (ILCs) were offered, focused on the measurement of ionizing radiation in the environment, for protection of human health (including medical applications of ionizing radiation) and for the safety of the workplace. Some areas in which comparisons were offered were in innovative fields in which an ILC had never been previously offered in Italy, e.g. an ILC on the measurement of the activity/surface emission rate of wide area sources and an ILC on measurement of activity of radionuclides for medical use in nuclear medicine, using “dose calibrators”.

The participation to the first edition of the program proved very successful, attracting a total of nearly 150 participants from public and private entities across the Italian territory [De Felice et. al. 2025]. Organising such a large program was also an opportunity for improvement through the adoption of approaches based on digitalization. ENEA-INMRI has improved its digital skills by adopting ILC methodologies for the organisation, data management, data analysis, and automated technical report generation, all in response to the evolving challenges of digital transformation [Iafrati et. al., 2024]. Building on this success in January 2025, funded again by MIMIT for 2 years, ENEA-INMRI launched the second National Program for the Promotion of the Reliability of Measurements of Ionizing Radiation based on ILCs. This new edition of the Program stems from the success of the first edition and introduces a broader project that also involves the National Institute of Metrology Research (INRiM) with an ILC on quantitative magnetic resonance imaging. It is worth noting that the Italian NMI organization includes ENEA-INMRI for ionizing radiation-related quantities and the larger INRiM for the base SI units and several more.

According to the Italian law, both institutes serve as primary metrology institutes within their respective areas of expertise. In addition to the development and maintenance of primary standards, both are actively and significantly involved in the dissemination of quantities and the provision of calibration services. In this regard, ILCs are regularly offered as recognized methods to verify technical competences of accredited or non-accredited calibration and test laboratories according to ISO 17025 and to validate the measurement methods of final users.

These capabilities include the correct use of traceability, the use of adequate methods, and the proficiency of the staff involved in all operations such as handling, measurements, data management, and reporting.

This ILC approach is fully aligned with the theme of World Metrology Day 2025, “Measurements for all times, for all people." In particular, it represents the most effective way to bridge the gap between traceability and measurements, providing a concrete, freely accessible methodology to improve the reliability of measurements and, therefore, the quality of life for all citizens.

The new ILC National Program will consolidate or start a new path of continuous improvement in the quality of measurements and, consequently, in the services offered to citizens, broadly covering medical, environmental, and food safety applications.

Innovative ILCs that have not yet been explored in Italy will be proposed, such as dosimetry in HDR brachytherapy with Ir-192 sources, patient dosimetry with Kerma-Area Product (both curated by ENEA-INMRI), and quantitative Magnetic Resonance Imaging (curated by INRiM). In addition to these topics, the Program's definition is agreed upon with a Scientific Committee to highlight the country's priorities among a wide range of subjects: nuclear medicine with radiopharmaceuticals, radionuclide activity in solid food matrices, radon activity in air/water, measurement of ambient dose equivalent H*(10) in facilities with direct or indirect neutron production, and measurement of surface contamination with extended planar sources (EPS).

A considerable number of participants have already been enrolled in the ILC dedicated to brachytherapy thanks to the Italian medical physics association (AIFM) and efforts are underway to promote the ILC Program and define its working groups. In medical applications, Program participants may include several hundred medical diagnostic laboratories and radiotherapy centres in the nation's territory, as well as laboratories providing environmental and personal dosimetry services. In the environmental sector, the main operators consist of the Italian Regional Environmental Protection Agencies and the associated laboratories, the Italian Higher Institute for Environmental Protection and Research (ISPRA), the Italian Institute for the Insurance against Incidents on the Workplace (INAIL), nuclear operators and the nuclear regulatory authority (ISIN), as well as measurement facilities ranging from universities to research centres. An intensive, continuous, and multi-focus ILC program will positively impact the quality of life of any citizen, patient, or professional living in the monitored environment or consuming products produced in the environment itself.

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Measurement for All times, for All people
Kenya Bureau Standards SSDL

Grace Ateka, Kenya Bureau Standards SSDL (KEBS), Kenya

The Kenya Bureau of Standards (KEBS) SSDL was established in 2008 in collaboration with the IAEA. The KEBS SSDL serves as the custodian of the national measurement standards in ionizing radiation and plays a crucial role in promoting accurate dosimetry measurements – ensuring measurement for all times, for all people.

Dosimetry is a critical field that underpins safety and health in radiation exposure across various sectors. The World Metrology Day 2025 theme, "Measurement for all times, for all people", emphasizes the need for universal access to accurate dosimetry practices. As technology evolves, so must our commitment to enhancing dosimetry methods and ensuring equitable protection for all individuals regardless of their circumstances.

There is a growing demand in the modern world for accurate and reliable measurements, especially in the health sector. This is particularly important due to the rising incidence of cancer, which necessitates precise measurements in prevention, diagnosis, and treatment. Accurate measurement cannot be achieved without appropriate calibration. In Kenya, the government has taken a step forward by making calibration mandatory through the Business Laws (Amendment) Act, No. 20 of 2024.

In line with this year's theme, the main tasks of the KEBS SSDL are to:

- Realize and maintain the national measurement standards;
- Provide measurement traceability to the International System of Units (SI);
- Bridge the gap between Primary Standards Dosimetry Laboratories (PSDLs) and users of ionizing radiation by offering calibration services to end users.

Currently, the Laboratory provides calibration services in radiation protection and radiotherapy. For **radiation protection**, the Lab offers calibration in terms of air kerma, personal dose equivalent, and ambient dose equivalent. Its radiotherapy calibration capability has recently been established, in terms of absorbed dose to water and air kerma.

Additionally, the KEBS SSDL offers personnel monitoring services, and radiotherapy audits. With support from the IAEA, the laboratory is equipped with X-ray, Cs-137, and Co-60 calibration systems to serve industries and hospitals. It also boasts a fully automated Optically Stimulated Luminescence (OSL) system with the latest technology, including a robotic arm that ensures accurate and efficient readings.

Fig. 1 Acceptance, testing and commissioning of the irradiator for therapy calibrations, (picture provided by KEBS).

The Laboratory is accredited by the German accreditation body (DAKKs) and participates in biannual intercomparison exercises with the IAEA. Its Quality Management System (QMS) is also approved by AFRIMETS. Traceability is maintained through the IAEA and other recognized primary laboratories.

As technologies continue to evolve, achieving accurate measurement for all times and all people will remain dependent on robust calibration practice.

Enhancing Diagnostic Radiology in Nigeria through the Establishment of Diagnostic Beam Qualities at the Secondary Standard Dosimetry Laboratory

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National Institute of Radiation Protection and Research, Nigeria

1. Introduction

Diagnostic radiology is essential in healthcare delivery, significantly influencing patient diagnosis and treatment strategies. The effectiveness and safety of diagnostic radiography rely upon precise dosimetry, which aids the image quality and patients' protection from excessive radiation exposures in diagnostic radiology [1]. Establishing and sustaining specified diagnostic beam quality ensures that radiological operations comply with international standards, hence enhancing patient care and safety. SSDLs are essential for achieving this, as they offer calibration services, help in the standardization of radiation measurements, and function as essential reference points for diagnostic radiology facilities, ensuring consistency and accuracy in diagnostic radiology activities [2 – 4].

Prior to the development of its capabilities for diagnostic radiology at the SSDL in Nigeria, the dosimetry of diagnostic radiology has been devoid of comprehensive national standards, resulting in unpredictability and inconsistency in radiation measurements. Dosimetry practices frequently relied on external calibration sources or informal calibration and verification techniques, leading to diminished trust in dose precision and potentially increased patient risk. The lack of specialized SSDL services for diagnostic radiography resulted in considerable discrepancies in the standardization of beam quality and dosimetry protocols among Nigerian healthcare institutions. These constraints impeded efficient quality control and radiation safety initiatives, presenting significant dangers to patient care [1, 4].

The establishment of relevant beam qualities such as RQR, RQA, and RQT enhances national and international trust in radiological procedures, fortifies radiation protection infrastructure, and promotes the ongoing advancement of healthcare services [4 – 6]. Adopting the diagnostic beam standards significantly increases the precision and dependability of dosimetric practices, thereby synchronizing national protocols with international benchmarks, while greatly boosting patient safety and the overall quality of diagnostic radiography services. Therefore, it was essential to establish these standards through specific diagnostic beam qualities at the Nigeria's SSDL.

This article discusses the diagnostic beam qualities at the Nigerian SSDL, developed in accordance with IAEA TRS 457 and IEC 61267 guidelines. It outlines their technical specifications and how SSDL activities enhance diagnostic radiology, improve patient safety, and advance healthcare in Nigeria.

2. Materials and Methods

2.1 Beam Quality and Protocol

Four diagnostic beam categories were established according to IEC 61267 and IAEA TRS 457 guidelines: RQR (unfiltered), RQA (Al-filtered) and RQT (Cu-filtered). These guidelines define the specified tube voltages, filtration parameters, and acceptable half-value layer (HVL) ranges to maintain consistency in diagnostic X-ray beams. The HVL of each beam, as the principal metric for beam hardness and quality, was assessed and juxtaposed with reference values from IEC 61267 and IAEA TRS 457 to verify compliance.

2.2 X-ray Generator

A Hopewell X200 X-ray system produced the reference beams over a range of diagnostic voltages (0–225 kV). Equipped with a tungsten-anode Comet tube, 1 mm beryllium filtration, and dual focal spots (1.2 mm and 4.0 mm), the machine was programmed for each beam quality (RQR, RQA, RQT, RQR-M) by selecting the appropriate kilovoltage and tube current–time product (mAs).

2.3 Dosimetry Equipment

An Exradin A4 ionization chamber (300 cm³) and PTW UNIDOS served as the reference dosimeter, traceable to the IAEA Dosimetry Laboratory. The PTW UNIDOS electrometer recorded the charge collected by the chamber, corrected for temperature and pressure to yield air kerma values. System checks for zero offset and leakage were performed prior to each measurement series. The air kerma rate, $\dot{K}$, was then determined using equation 1:

$$\dot{K} = N_k M_E k_{T,P} \quad (1)$$

where:

$\dot{K}$ is the air kerma rate (mGy/s) for a particular mAs;
N_k is the reference calibration coefficient (mGy/nC);
M_E is the electrometer reading;
$k_{T,P}$ is the temperature-pressure correction factor calculated using equation 2

$$k_{T,P} = \frac{(273.2+T)P_{ref}}{(273.2+T_{ref})P} \quad (2)$$

where P_{ref} and T_{ref} are the reference pressure and temperature respectively, P and T are the laboratory measured pressure and temperature.

2.4 Beam Attenuators (Filters)

Aluminium (Al) and copper (Cu) filters of verified thickness and 99.9% purity were used to establish beam qualities. These filters were free of surface defects and their thickness verified using a micrometre. Heavier aluminium filtration hardened the beam to simulate attenuated radiographic conditions (RQA) or to set baseline HVLs (RQR) and Cu combined with Al was used to produce higher-energy beams resembling computed tomography spectra (RQT).

2.5 Establishing Beam Qualities

Beam qualities were generated as per IAEA TRS 457. Each RQR beam's nominal voltage was set (e.g., 70 kV), and its HVL measured with incremental Al filtration until matching the standard. Additional Al filters converted RQR beams to RQA, yielding higher HVLs. For RQT, copper plus aluminium filtration was added at higher voltages (e.g., 120 kV) to achieve the required beam hardness.

2.6 HVL Measurement Procedure

To determine HVLs, the ionization chamber's readings with and without incremental filters were compared, plotting transmitted intensity against filter thickness on a semi-log scale. The first HVL was identified where transmitted intensity reached 50% of the unattenuated beam; the second HVL (25% transmission) validated the homogeneity coefficient. A fixed source-to-chamber distance of 100 cm and narrow-beam geometry were used, with the filter wheel at 50 cm from the focal spot as illustrated in Fig 1. If a measured HVL fell below the reference range, filtration thickness was increased iteratively based on exponential attenuation principles. Once the required HVL was achieved, the beam was documented for use as a traceable reference for calibration of field instruments.

2.7 Measurement Uncertainty

Uncertainty was evaluated following references [7 – 9]. Type A (statistical) uncertainties captured random fluctuations from repeated measurements, while Type B (systematic) uncertainties covered calibration transfers, detector positioning, and system stability. The expanded uncertainty (k=2) across the three diagnostic beam qualities was 4–5%, affirming high confidence in all dosimeter measurements performed at the SSDL.

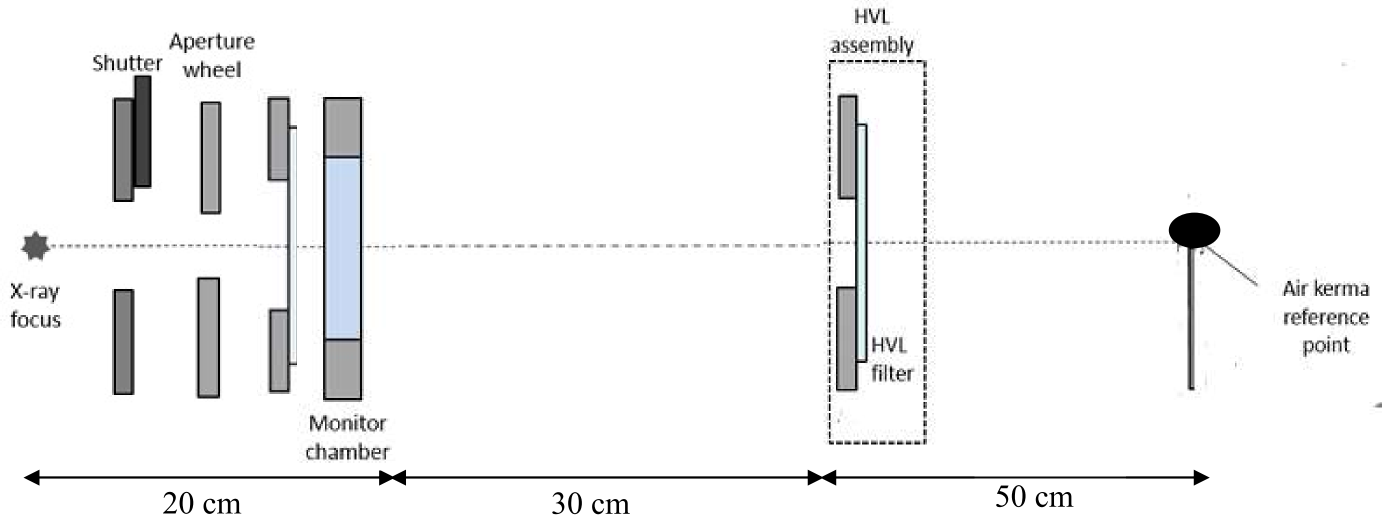

Fig. 1. Experimental setup

3. Results

The measured half-value layers (HVLs) for RQR beam qualities were within approximately 3% (0.33–2.71%) of the standard values, with homogeneity coefficients (ratio of the first to second HVL) aligning with published reference data (±0.03).

For RQA beam qualities, the specified Al filtration effectively hardened the initial RQR beams, resulting in HVLs that varied by less than 3% (0.91–1.98%). This outcome validates the appropriate filtration process and ensures compliance with established reference values.

RQT beam qualities, produced by augmenting Al with Cu filters, exhibited measured HVLs that deviated by no more than 3% (1.19–2.90%) from the nominal values within the computed tomography (CT) energy range of 100–150 kV.

The expanded uncertainty (k=2) across all beam qualities established was also 5%. Overall, these results confirm that the SSDL's established diagnostic beam qualities closely adhere to globally recognized specifications [4, 5], ensuring accurate reference conditions for dosimetry in diagnostic radiology.

4. Discussion

Each beam quality is tailored to fulfil a distinct role in diagnostic radiology. RQR beams reproduce the unfiltered outputs of general radiographic systems, whereas RQA beams model attenuated spectra following patient-like filtration and RQT beams emulate the extensively filtered, elevated-energy conditions observed in computed tomography (CT). The beam qualities established at the Nigerian SSDL show significant alignment with globally reference standards [4, 5] across the RQR, RQA and RQT classifications.

Measured HVLs and homogeneity coefficients consistently remain within acceptable ranges of (±0.03) generally varying by merely 1–3% from reference values. These small differences, generally attributed to variations in tube output, filter thickness, and detector behaviour confirm that the generated beams effectively replicate globally recognized "reference radiation conditions." In particular, the air kerma ratio remained near 0.5, ensuring that each beam's HVL was precisely set according to international guidelines.

The coefficients of homogeneity across all four categories exhibit a close correlation with the International Electrotechnical Commission (IEC) values, which signifies a persistent spectral configuration. The precision ensures that dosimeters calibrated on these radiation beams produce dependable measurements, with negligible deviation within acceptable parameters.

5. Conclusion

The Nigerian SSDL has developed a thorough reference for diagnostic radiology dosimetry that conforms to international standards, thereby ensuring traceability and compatibility on a global scale. This achievement impacts clinical practices by enabling in-country calibration of diagnostic ionization chambers, dose-area product meters, and other diagnostic radiology dosimeters, thus decreasing reliance on external laboratories and improving quality assurance measures. As a result, healthcare facilities across Nigeria can attain improved consistency and accuracy in dose monitoring, which enhances patient safety and image quality. The availability of these beam qualities enhances the capacity of Nigeria SSDL to participate in international dosimetry comparisons, thereby fostering global confidence in its calibration infrastructure.

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From Ideas to Action: How the SSDL in Poland Changed National Oncology

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'Poland should have, like every country, its own radium institute.'
The fascinating story of the creation of the Radium Institute in Poland begins with the words uttered by Maria Skłodowska-Curie during a meeting with the Polish community living in Chicago in 1921. This momentous utterance became the inspiration for the establishment of a facility which, over the following decades, was to play a key role in the development of radiation science and radiotherapy. The history of the Radium Institute is a tale of passion, determination and the constant strive for excellence, despite the numerous challenges it faced [1].

Origins and development

The first milestone in the history of the institution was the official opening of the Radium Institute on 29 May 1932. Shortly afterwards, in 1936, the Physical Laboratory with an X-ray Calibration Laboratory was added to its structures, allowing the scope of radiation research to be expanded and the first methods of calibrating measuring equipment to be developed. This made the facility one of the most important research centres in Poland, which influenced the development of medical technology and life sciences.

Reconstruction and transformation

The process of reconstruction and reorganization began after the Second World War. Some branches of the Radium Institute were restored, while new ones were established - in Krakow and Gliwice - to support the development of radiation research in various scientific fields. A turning point came in 1984, when the institution was renamed the Maria Skłodowska-Curie Oncology Centre - Institute. This change of name reflected the development of the institution and the growing importance of oncological research in medicine. As well, it emphasized the legacy of the eminent scientist, whose ideals became the foundation for a new stage in the Institute's history.

Modern identity and organisational structure

Today, the former Radium Institute functions as the Maria Sklodowska-Curie National Research Institute of Oncology. Within the structure of the Institute, the Secondary Standards Dosimetry Laboratory, which is an integral part of the Medical Physics Department, occupies a special place. This Laboratory specializes in the precise calibration of radiation dose measurement equipment, which is essential for ensuring the safety and efficacy of cancer therapies.

Role in international scientific collaboration

The Secondary Standards Dosimetry Laboratory is a member of the SSDL Laboratory Network [2] established by the IAEA and the World Health Organisation (WHO). Membership of this Network enables the facility to work closely with the Network's other members, international agencies, and renowned research institutes. As part of this collaboration, regular interlaboratory comparisons are carried out, including both the calibration of ionization chambers and the measurement of doses by TLD (thermoluminescence dosimetry). Such international comparisons are extremely valuable as they not only allow the results obtained to be verified but also fulfil accreditation requirements, which is an essential element in maintaining high quality standards.

Accreditations and Quality Standard

SSDL's accreditations (accreditation certificate No. AP 155 and No. AB 1499) in accordance to the ISO/IEC 17025 standard, granted by the Polish Centre for Accreditation, confirm compliance with the highest standards in the provision of calibration and dosimetry services [2]. Attention to the quality of services provided is particularly important in the context of cooperation with centres providing teleradiotherapy and brachytherapy in Poland. The high level of precision and reliability of measurements guarantees the safety of patients, and the effectiveness of the therapies performed. It should be noted that the Polish SSDL is the only laboratory in the country with SSDL status, which makes it a key centre for the calibration of dosimetry sets consisting of an ionisation chamber and an electrometer.

Dosimetry audits and continuous improvement

In addition to the routine calibration of dosimetry kits, the SSDL collaborates with national radiotherapy centres by conducting an annual external dosimetry audit using the TLDs [2]. These audits are extremely important as they allow the assessment of compliance of measurement procedures with international standards and the introduction of necessary improvements in testing methodology. Regular audits ensure that the highest quality standards are maintained, which has a direct impact on patient safety and the effectiveness of oncological therapies.

Interdisciplinary research and unique research facilities

One of the most innovative elements of the Institute's current activities is the collaboration between different research departments. The National Cancer Institute has projects that combine dosimetric research with experimental oncology in the broadest sense. The Polish SSDL has a ^{60}Co unit (Theratron 780E). Thanks to this device, it is possible to irradiate laboratory mice and cell cultures [3], which is the basis for research on the effects of radiation on the human body. Among other things, this research is aimed at detecting the first signs of cancer, analysing the mechanisms of cell damage and developing targeted oncological therapies. The use of modern research methods also makes it possible to create prognostic models that can help improve the effectiveness of treatment and early diagnosis of cancer.

Technological innovation and auditing of advanced treatment methods

In collaboration with the dosimetry team, which is part of the Medical Physics Department, a number of studies are being carried out on the possibility of extending dosimetry audit methods. Particular attention is being paid to the evaluation of modern helical patient treatment methods, a rapidly growing area of radiotherapy. The implementation of TLD audits in the context of these advanced technologies is essential to ensure full quality control and safety of the procedures used. In addition, a parallel dosimetric audit for brachytherapy will be carried out, allowing a comprehensive assessment of all oncological treatments used in Poland.

Importance for national radiotherapy centres and the future of the Institute

Based on almost a century of tradition and the experience of generations of scientists and doctors, the Institute is the foundation for the development of national radiotherapy centres. Thanks to ongoing cooperation with numerous medical institutions, the Institute not only carries out research, but also actively supports the training and development of specialists in the field of medical physics. High quality standards, confirmed by numerous accreditations, enable the Institute to take on new challenges and implement innovative technologies. Prospects for development include further international integration, expansion of research into new treatment methods and continuous improvement of control processes, all of which will contribute to raising the level of medical care in Poland.

Conclusions

Reflecting on nearly a century of history, the Radium Institute – now the Maria Sklodowska-Curie National Research Institute of Oncology – has undergone a remarkable evolution, from the visionary ideas of its pioneering founder to addressing today's scientific and technological challenges. Thanks to interdisciplinary integration and strong international and national collaborations, the Institute has become an example of a research institution that is constantly seeking new solutions to improve the quality of oncological therapies. The Polish SSDL, at the heart of the Department of Medical Physics, plays a key role in ensuring patient safety and supporting innovative solutions in the field of radiotherapy, thanks to its unique infrastructure and the implementation of modern control methods.

The importance of constant quality control and precise calibration of radiation doses as the basis for successful cancer treatment cannot be overstated. Combining tradition and modernity, the Institute looks resolutely to the future, supporting the country's radiotherapy centres and meeting the challenges of the dynamic development of medical technology. Investments in research and the development of professional skills are a guarantee that Poland will continue to maintain a high level of medical care, taking advantage of the latest advances in science and technology.

The history of the Radium Institute is not only a testimony to past achievements, but also an inspiration for future generations of scientists, doctors and medical physicists. Thanks to its long tradition, innovative solutions and international cooperation, The Maria Sklodowska-Curie National Research Institute of Oncology remains a pillar of Polish science and medicine, ensuring safe, effective and modern radiotherapy for all patients in Poland.

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The Development of Ionizing Radiation Metrology in Thailand

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Historical Perspectives

The Office of Atoms for Peace (OAP) in Thailand is the primary agency responsible for regulating safety in the use of radiation sources and protecting the public from radiation hazards. It also oversees the establishment, maintenance, development, calibration, and dissemination of national standards for radiation and radioactivity measurements in accordance with international measurement units.

In 1976, the IAEA invited Member States to apply for assistance in establishing radiation measurement standards. In response, OAP received support to establish SSDL-OAEP (Office of Atomic Energy for Peace) for radiation protection purposes. Additionally, the Department of Medical Sciences (DMSc) under the Division of Radiation Protection Services (DRPS) received assistance to set up SSDL-DMSc for medical radiation measurement standards.

OAP later upgraded its laboratory into a 111-square-meter radiation-shielded room, equipped with essential instruments. Between 1981 and 1986, six standard irradiators were installed, and SSDL-OAEP received three sets of secondary standard dosimetry equipment for radiation measurement. Over the past 10 years, these measurement systems have remained stable, with a measurement uncertainty of no more than ±5% compared to reference radiation sources. Additionally, with support from the IAEA, including training funds and expertise, the radiation-shielded room was equipped with precision positioning systems, distance measurement tools, CCTV, radiation monitors, and alarm systems. To address calibration challenges for instruments measuring lower-energy radiation compared to gamma radiation from Cesium-137, SSDL-OAEP sought further assistance from the IAEA under the "Upgrading SSDL-OAEP" project from 1990 to 1991. This led to the acquisition of a low-energy X-ray machine and its necessary accessories.

Since its establishment, SSDL-OAEP has been maintained and operating, providing calibration and adjustment services for various radiation measurement instruments. It ensures that all radiation measurement devices in the country undergo annual calibration, guaranteeing measurement reliability and providing safety recommendations for the use of radiation and radioisotopes.

Designated Institute (DI) for Ionizing Radiation

Thailand's radiation metrology has steadily advanced over the years. In 2004, OAP and the National Institute of Metrology (NIMT) signed a memorandum of understanding to develop national measurement standards for ionizing radiation. Under this agreement, OAP led national and international collaboration efforts, while NIMT supported on strengthening the national measurement system by ensuring the accurate transfer of standards to users across the country and gaining international recognition.

As the national regulatory body, OAP today sets safety standards for radiation testing, calibration, and personal dosimetry laboratories. Its efforts led to official membership in the Asia Pacific Metrology Programme (APMP), reinforcing its international role in radiation metrology.

Collaboration to Support Becoming a PSDL

OAP launched a project to upgrade Thailand's national radiation measurement standards from the secondary to the primary level, enhancing the country's measurement capabilities. This initiative supported the establishment of the Nuclear and Radiation Operations Building, completed in 2022, further strengthening national calibration and metrology capabilities while ensuring compliance with international standards and advancing radiation measurement technologies. The goal was to establish OAP as a regional center for ionizing radiation metrology within the Association of Southeast Asian Nations (ASEAN). Thailand would become the sixth in the Asia-Pacific region to develop a primary standard radiation measurement system, following Australia, China, Japan, the Republic of Korea, and Taiwan, and the first Primary Standards Dosimetry Laboratory (PSDL) in ASEAN.

The initial phase of this project, which began in 2017, was driven by academic collaboration with the European Union (EU). This included support in laboratory design, training, and scientific visits to the National Physical Laboratory (NPL) in the United Kingdom and through the APMP. Further training and visits took place at the Korea Research Institute of Standards and Science (KRISS) and the National Metrology Institute of Japan (NMIJ). After detailed planning with these institutions, OAP procured primary standard radiation measurement instruments from KRISS, including:

1. Graphite Cavity Chambers with diameters of 19 mm and 39 mm for air kerma from gamma rays,
2. Free Air Ionization Chambers (FAC) for air kerma from low-energy X-rays, and
3. Free Air Ionization Chamber (FAC) for air kerma from medium-energy X-rays.

The installation of primary standard instruments took place between 2018 and 2019, with experts from Australia, China, Japan, and the Republic of Korea, providing consultation. Following installation, measurements from the Graphite Cavity Chambers and Free Air Ionization Chambers were compared with those from KRISS and NMIJ.

To demonstrate its capability as a PSDL, OAP published technical papers on establishing the primary standard radiation measurement system. The first primary standard developed was air kerma measurement from a Cs-137 source for radiation protection, using the Graphite Cavity Chamber as the primary standard detector. Before implementation, correction factors and physical constants were evaluated through experimental methods and the Monte Carlo method. Air kerma and measurement uncertainty were then assessed according to ICRU 37 and ICRU 90 standards. A comparison with KRISS and NMIJ showed a difference of less than 1%, confirming the accuracy and reliability of OAP's measurements.

Currently, OAP's standard dosimetry laboratory is accredited to ISO/IEC 17025 by the Thai Industrial Standards Institute (TISI) across 24 measurement scopes—12 in primary and 12 in secondary standards. Plans are underway to expand accreditation to cover all necessary measurement ranges, particularly in primary standard radiation measurements, with full coverage targeted by 2027. Additionally, OAP has submitted 10 Calibration and Measurement Capabilities (CMCs) for official recognition by the International Bureau of Weights and Measures (BIPM), which was already peer-reviewed by NMIJ experts. Once approved, Thailand would be the first ASEAN country to list its primary standard calibration and measurement capabilities on the BIPM/CIPM key comparison database.

Four primary standards have been transferred to secondary standards (among which are three SSDLs in Thailand) and end-users through metrological traceability. These include the measurement of absorbed dose in water for high-dose radiation, air kerma measurement for Cs-137, radiation measurement for low-energy X-rays and mammography, and radiation measurement for medium-energy X-rays for diagnostics and radiation protection. This transfer is conducted through the calibration of various radiation measuring instruments, including radiation detectors, survey meters, portable dosimeters, and transfer dosimeters such as Alanine, OSL, and TLD.

Support to others

OAP has expanded the transfer of primary standards through inter-laboratory comparison programs, involving standard dosimetry and individual monitoring service (IMS) laboratories across ASEAN. These programs, led by OAP, help laboratories validate their competency for ISO/IEC 17025 accreditation and enhance the safety of nuclear and radiation technology by ensuring reliable testing and calibration services. During the Occupational Radiation Protection Appraisal Service (ORPAS) mission in Thailand in March 2024, IAEA experts recognized OAP's good practices, particularly its inter-laboratory comparison efforts, which strengthen domestic laboratory capabilities and build user confidence.

Future

Looking ahead, OAP will remain committed to advancing radiation measurement standards across all applications, ensuring safety for workers, the public, and the environment. Furthermore, OAP will continue to support measurement activities in ASEAN's radiation standard laboratories, fostering regional collaboration and development. Together - we move forward.

The Development in Diagnostic Radiology Calibration at SSDL Thailand

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The main responsibility of the Secondary Standard Dosimetry Laboratory at the Bureau of Radiation and Medical Devices, Ministry of Public Health, Thailand, is to maintain calibration traceability in the medical field at therapy, diagnostic, and radiation protection levels.

For diagnostic levels, RQR and RQT beam qualities can be calibrated in terms of air kerma and air kerma rate, following the IAEA technical protocol TRS-457 since 2008. The calibration bench and beam qualities were established by an expert from Germany. These beam qualities are traceable to the SI unit through the German National Metrology Institute (PTB) and are accredited under ISO/IEC 17025 by the national accreditation body of Thailand. In 2020, KAP meters became eligible for calibration in terms of air kerma-area product for RQR beams. To further enhance diagnostic calibration in the medical field, a new X ray machine (shown in Fig. 1), featuring two targets – Molybdenum and Rhodium – was installed in 2023.

Fig 1. X-ray machine maintained at the SSDL.

The procedures and half-value layer (HVL) requirements for X ray beam qualities are described in IEC 61267. Mammography beam qualities are based on three types of anodes – molybdenum (Mo), rhodium (Rh), and tungsten (W) – with additional filtration materials such as molybdenum, rhodium, aluminium, and silver, which can be used to provide standard beam qualities in the energy range of 20 to 60 kV. A 6 cm³ free-air ionization chamber (type 34069), traceable to PTB, was used to measure the HVL and air kerma rate at a distance of 100 cm from the X ray tube's focal spot. The additional filtration and tube voltage (kV) were adjusted to achieve the standard HVL values. To verify the calibration results, a comparison with the IAEA and an evaluation of the associated uncertainty were carried out.

Currently, the SSDL of the Bureau of Radiation and Medical Devices can provide calibration services for most diagnostic beam qualities. In recent years, diagnostic dosimeters have been calibrated using RQR, RQT, and mammography beam qualities with a total of 251 calibrations performed.

These calibration services support diagnostic quality assurance and assist medical physicists in improving patient dosimetry in hospitals. The continued development of the SSDL helps expand traceability and ensure accurate dosimetry for end-users.

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Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose To Water (**Technical Reports Series No. 398 (Rev. 1)**), February 2024
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Quality Assurance and Optimization for Fluoroscopically Guided Interventional Procedures | IAEA

Dosimetría en Braquiterapia - Código de Práctica Internacional para Laboratorios Secundarios de Calibración Dosimétrica y Hospitales (**Technical Reports Series No. 492**) **Spanish**, May 2025
Dosimetría en Braquiterapia - Código de Práctica Internacional para Laboratorios Secundarios de Calibración Dosimétrica y Hospitales | OIEA

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Courses, Meetings and Consultancies in 2025

TC Courses and Workshops related to DMRP activities

- RAS6098: Regional Training Course on Optimization of Re-Irradiation in Palliative Care, Kuala Lumpur, Malaysia, 12 – 16 May 2025
- RAS6106: Regional Workshop on Streamlined and Emerging Theranostics Techniques, Bangkok, Thailand, 9 – 13 June 2025
- RAS6112: Regional Training Course on Neutron Calibration and Onsite Intercomparison, Riyadh, Saudi Arabia, 22 – 26 June 2025
- RER6040: IAEA/ESTRO Training Course on Target Volume Determination, Bucharest, Romania, 25 – 27 June 2025
- RAF6060: Regional Training Course on The Use of Artificial Intelligence in Medical Imaging for Medical Physics, Cairo, Egypt, 4 – 8 August 2025
- RAF6060: Regional Training Course on Train the Trainers on Women Cancers from Diagnosis to Treatment, Vienna, Austria, 8 – 12 September 2025
- RER6040: IAEA/ESTRO Training Course on Advanced Treatment Planning, Budapest, Hungary, 2 – 6 November 2025
- RER6040: IAEA/ESTRO Training Course on Palliative Care and Radiotherapy, Cologne, Germany, 16 – 18 November 2025

Training courses

- Joint ICTP–IAEA Workshop on Quality Assurance and Dosimetry in X-ray Breast Imaging, Trieste, Italy, 26 – 30 May 2025
- Joint ICTP–IAEA Workshop on Reference Dosimetry for External Beam Radiotherapy and Brachytherapy, Trieste, Italy, 3 – 7 November 2025

DMRP Meetings and Consultancies

- Consultancy Meeting to Update the Technical Reports Series No. 430 “Commissioning and Quality Assurance of Computerized Planning Systems for Radiation Treatment of Cancer”, Vienna, Austria, 6 – 9 May 2025
- Second Technical Meeting of Dosimetry Audit Networks, Vienna, Austria, 9 – 12 June 2025
- Consultancy Meeting on Preparation of the International Symposium on Standards, Applications and Quality Assurance in Medical Radiation Dosimetry (IDOS-2026), Vienna, Austria, 10 – 13 June 2025
- First Research Coordination Meeting on Doctoral CRP in Advanced Dosimetry and Radiation Metrology, Vienna, Austria, 23 – 27 June 2025
- Third Research Coordination Meeting on Evaluation of the Dosimetry Needs and Practices for the Update of the Code of Practice for Dosimetry in Diagnostic Radiology (TRS-457), Vienna, Austria, 13-17 October 2025
- First Research Coordination Meeting on Advanced Tools for Education, Audit and Quality Assurance in Radiopharmaceutical Therapy Dosimetry, Vienna, Austria, 3 – 7 November 2025
- Consultancy Meeting on Update of the Human Health Series No. 19 and spectral CT guidelines, Vienna, Austria, 17 – 21 November 2025
- Third Research Coordination Meeting on Development of Methodology for Dosimetry Audits in Brachytherapy, Vienna, Austria, 24 – 28 November 2025
- First Research Coordination Meeting on Establishing a Sustainable Network for Data Collection in Radiation Medicine, Vienna, Austria, TBD

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