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Review Article

Metrology in the context of ionizing radiation regulatory bodies

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Abstract: This paper analyzes the role of metrology in the regulation of activities involving ionizing radiation in Brazil, highlighting its relevance in ensuring the reliability of measurements used in regulatory processes. The regulation of these activities is carried out by different governmental bodies, particularly the National Nuclear Safety Authority (ANSN), the Brazilian Health Regulatory Agency (ANVISA), and the Ministry of Labor and Employment, and is based on three main stages: the establishment of standards and regulations, licensing and authorization processes, and inspections and audits. In all these stages, metrology plays a central role by ensuring comparability and traceability of measurement results. The paper also discusses the integration of the Brazilian metrological infrastructure into the international context, emphasizing the importance of institutions and agreements such as the BIPM, ILAC, OIML, and the CIPM MRA, which are responsible for ensuring the international recognition of measurement standards and results. At the national level, the role of the National Institute of Metrology, Quality and Technology (INMETRO) is highlighted as the body responsible for coordinating the Brazilian metrological system, as well as the role of the National Laboratory of Ionizing Radiation Metrology (LNMRI) as the designated laboratory for ionizing radiation. In addition, the paper analyzes the operational measurement infrastructure in Brazil, which includes calibration laboratories, testing laboratories, individual monitoring services, and radiometric analysis laboratories, all linked to accreditation networks coordinated by Cgcre/Inmetro and CASEC. In this context, the reliability of measurements depends on metrological traceability to the International System of Units (SI) and on the proper integration of the different levels of the metrological infrastructure. Finally, it is concluded that although Brazil has a robust metrological infrastructure aligned with international standards, there is still no evidence that the installed capacity is sufficient to fully meet national demand. Therefore, the need for systematic assessments of the existing infrastructure and for strengthening actions aimed at ensuring metrological traceability and radiological safety in the country is emphasized.

Keywords: Metrology, Ionizing radiation, Regulatory body, ANSN

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Metrologia no contexto dos órgãos reguladores das radiações ionizantes

Resumo: O presente trabalho analisa o papel da metrologia na regulação das atividades que envolvem radiações ionizantes no Brasil, destacando sua relevância para a garantia da confiabilidade das medições utilizadas nos processos regulatórios. A regulação dessas atividades é conduzida por diferentes órgãos governamentais, especialmente a Autoridade Nacional de Segurança Nuclear (ANSN), a Agência Nacional de Vigilância Sanitária (ANVISA) e o Ministério do Trabalho e Emprego, e baseia-se em três etapas principais: estabelecimento de normas e regulamentos, processos de licenciamento e autorização, e realização de inspeções e auditorias. Em todas essas etapas, a metrologia desempenha papel central, ao assegurar a comparabilidade e a rastreabilidade dos resultados de medição. O trabalho também discute a inserção da infraestrutura metrológica brasileira no contexto internacional, ressaltando a importância de instituições e acordos como o BIPM, a ILAC, a OIML e o CIPM MRA, responsáveis por garantir o reconhecimento internacional dos padrões e das medições. No âmbito nacional, destaca-se a atuação do Instituto Nacional de Metrologia, Qualidade e Tecnologia (INMETRO) como responsável pela coordenação do sistema metrológico brasileiro, bem como o papel do Laboratório Nacional de Metrologia das Radiações Ionizantes (LNMRI) como laboratório designado para a área de radiações ionizantes. Adicionalmente, o trabalho analisa a estrutura operacional de medições existente no país, composta por laboratórios de calibração, ensaio, monitoração individual e análises radiométricas, vinculados às redes de acreditação coordenadas pela Cgcre/Inmetro e pelo CASEC. Nesse contexto, evidencia-se que a confiabilidade das medições depende da rastreabilidade metrológica ao Sistema Internacional de Unidades (SI) e da adequada integração entre os diferentes níveis da infraestrutura metrológica. Por fim, conclui-se que, embora o Brasil possua uma infraestrutura metrológica robusta e alinhada aos padrões internacionais, ainda não há evidências de que a capacidade instalada seja suficiente para atender integralmente à demanda nacional. Dessa forma, ressalta-se a necessidade de avaliações sistemáticas da infraestrutura existente e do fortalecimento das ações voltadas à garantia da rastreabilidade metrológica e da segurança radiológica no país.

Palavras-chave: Metrologia, Radiações ionizantes, Agência Regulatória, ANSN

1. INTRODUCTION

In Brazil, activities involving any form of human or environmental exposure to ionizing radiation are regulated by the National Nuclear Safety Authority (ANSN) (1), the Brazilian Health Regulatory Agency (ANVISA) (2), and the Ministry of Labor and Employment (3).

In general, the regulatory process encompasses three primary stages:

- Standards and regulations, which specify the requirements that the regulated sector must fulfill to obtain an operating license;
- Licensing and authorization processes, in which the applicant describes their infrastructure and operational procedures, demonstrating the capacity to operate in accordance with the requirements established in the standards;
- Inspections and audits, conducted by competent authorities to verify compliance with the parameters approved during the licensing process.

Throughout all these stages, metrology plays a pivotal role, as it provides the essential means to ensure the reliability of the measurements used to demonstrate compliance with regulatory requirements.

2. THE ROLE OF METROLOGY IN THE REGULATION OF IONIZING RADIATION RESULTS AND DISCUSSIONS

Standards and regulations establish, among other aspects, limit values for the exposure of the general public, occupationally exposed workers, and for the release of radioactive material into the environment. These limits are aligned with recommendations from

international bodies, such as the ICRP (International Commission on Radiological Protection) (4) and the IAEA (International Atomic Energy Agency) (5).

Such values are adopted internationally and are based on extensive scientific and technical studies conducted by various international organizations. The possibility of utilizing measurement results obtained at different times and by different institutions is based on the assumption that all such results are comparable. This property is known as metrological traceability to the International System of Units (SI), maintained and administered by the BIPM (International Bureau of Weights and Measures) (6).

Licensed institutions must demonstrate, through measurements, reports, and audits, that they operate strictly in accordance with the parameters established in the licensing process. To this end, it is essential to demonstrate the reliability of the presented measurement results. This reliability depends, among other factors, on the metrological traceability of the measurements to the SI and the adequacy of the instrumentation used.

Furthermore, it is necessary to ensure that measuring instruments remain stable and appropriately calibrated over time. Similarly, measurements performed during inspections and audits conducted by regulatory authorities must also exhibit a high degree of reliability and metrological traceability.

Thus, it can be stated that ionizing radiation measurements constitute a central element in the process of demonstrating and verifying compliance with the requirements established by regulatory standards. The measurement process involves several aspects, such as:

- Appropriate instrumentation;
- Well-defined measurement procedures;
- The competence and experience of the professional responsible for the measurements;
- The metrological traceability of the results obtained.

The success of regulating activities that utilize ionizing radiation, therefore, presupposes the existence of a robust metrological infrastructure aligned with international standards.

3. INTERNATIONAL METROLOGICAL INFRASTRUCTURE

Metrology has been present since the dawn of civilization. However, the modern institutional structure of metrology began in 1875 with the signing of the Metre Convention in Paris, in which 17 countries participated, including Brazil.

The Metre Convention established the international metric system and created the BIPM (International Bureau of Weights and Measures), whose mission is to ensure the global uniformity of measurements. This uniformity is essential for various fields, including trade, science, industry, and safety. Currently, 64 countries are full member states of the Metre Convention.

In addition to the institutions directly associated with the International System of Units, other international organizations play an important role in the global metrological infrastructure:

- ILAC – International Laboratory Accreditation Cooperation: ILAC is the international organization for accreditation bodies responsible for assessing the competence of conformity assessment bodies. These bodies operate according to the ISO/IEC 17011 standard and perform the accreditation of:
    - Testing and calibration laboratories (ISO/IEC 17025);
    - Medical laboratories (ISO 15189);
    - Inspection bodies (ISO/IEC 17020).
- OIML – International Organization of Legal Metrology: OIML is an international organization focused on legal metrology, a field that addresses the mandatory

technical and legal requirements applicable to measuring instruments and pre-packaged products.

- CIPM MRA – Mutual Recognition Arrangement: The CIPM MRA is the international arrangement through which National Metrology Institutes demonstrate the international equivalence of their measurement standards and the calibration and measurement certificates they issue.

The outcomes of this arrangement are the internationally recognized Calibration and Measurement Capabilities (CMCs) of the participating institutes. These capabilities are evaluated through peer-review processes. Approved CMCs and associated technical data are publicly available in the international database known as the KCDB (Key Comparison Database).

The approved CMCs and their associated technical data are publicly available in the international database known as the Key Comparison Database (KCDB) (14).

Brazil is a signatory to all these agreements. This framework of international institutions and arrangements constitutes the foundation that confers reliability and credibility to measurements, enabling the secure exchange of knowledge and safety among nations.

The reliability of ionizing radiation measurements depends on the existence of a metrological traceability chain that connects field instruments to the international standards of the International System of Units (SI). This chain involves various institutional levels, ranging from international organizations to laboratories performing routine measurements. In a simplified manner, the metrological traceability chain can be represented by Figure 1.

Figure 1: Hierarchy of the internationally recognized metrological system.

Under this model, the BIPM maintains the international coordination of the International System of Units (SI) and promotes international comparisons among National Metrology Institutes (NMIs).

4. METROLOGICAL INFRASTRUCTURE IN BRAZIL

In Brazil, the National Institute of Metrology, Quality and Technology (INMETRO) serves as the National Metrology Institute (NMI) and is designated by the Brazilian State to coordinate and implement the national metrology system (15).

Its primary areas of activity include:

1. Scientific and Industrial Metrology: Development and maintenance of measurement standards, ensuring metrological traceability.
2. Legal Metrology: Establishment of technical requirements applicable to measuring instruments and the assessment of compliance with these requirements.

3. Conformity Assessment (Certification): Establishment of technical standards and regulations for products and services, ensuring safety, health, and environmental protection.
4. Accreditation (Cgcre): Accreditation of certification bodies, inspection bodies, and testing and calibration laboratories, attesting to their competence.

In addition to the laboratories maintained directly by INMETRO, there are two designated laboratories that operate under supervised delegation in specific areas of scientific metrology. These laboratories are:

- Time Service Division of the National Observatory (DSHO/ON);
- National Laboratory of Ionizing Radiation Metrology (LNMRI), part of the Institute of Radioprotection and Dosimetry (IRD/ANSN).

As Brazil's National Metrology Institute, INMETRO is responsible for maintaining national standards and ensuring their international equivalence through the CIPM MRA.

5. OPERATIONAL MEASUREMENT INFRASTRUCTURE IN BRAZIL

The national metrological infrastructure in the field of ionizing radiation involves several stakeholders, including:

- instrument calibration laboratories;
- individual monitoring services for radiation-exposed workers;
- testing and radiological control laboratories;
- radiometric analysis laboratories for samples.

Some of these laboratories operate as service providers, while others belong to the institutions that utilize or handle radioactive material. In this context, measurement reliability

is ensured through the periodic calibration of the instruments used (metrological traceability) and the implementation of appropriate quality management systems.

Two important components of this structure are:

- Cgcre (General Coordination for Accreditation): The official accreditation authority in Brazil, part of Inmetro's structure. It assesses, on a voluntary basis, the competence of laboratories, ensuring international recognition for their reports and certificates. Cgcre organizes laboratories into two main networks: the Brazilian Calibration Network (RBC) and the Brazilian Network of Testing Laboratories (RBLE). In the field of ionizing radiation, there are six accredited laboratories in the RBC and twelve in the RBLE.
- CASEC (Evaluation Committee for Testing and Calibration Services): Part of the structure of the Institute of Radioprotection and Dosimetry (IRD/ANSN), it is responsible for the technical evaluation and monitoring of the competence of laboratories involved in these activities. Currently, seven calibration laboratories and eight individual monitoring services hold CASEC authorization.

Regarding calibration laboratories, five hold both Cgcre accreditation and CASEC authorization. However, the scope of testing laboratories accredited by Cgcre (Table 1) is more diverse than that of CASEC, which focuses solely on evaluating individual monitoring services for workers.

Table 1: Tests and measurements performed by Cgcre-accredited laboratories (as of March 13, 2026).

Test	Samples	Quantity
Determination of metrological parameters	Medical X-ray emitting equipment	2
Individual monitoring of workers	Evaluation of individual monitors used by workers	3

Test	Samples	Quantity
Radioactivity measurements	Water, air, filters, soil, sediments, metallic and non-metallic minerals, food, and waste	6
Attenuation coefficient	Protective clothing; shielding material	1

6. THE ROLE OF LNMRI IN IONIZING RADIATION METROLOGY

The National Laboratory for Ionizing Radiation Metrology (LNMRI) serves as the designated laboratory of INMETRO for the field of ionizing radiation. In this capacity, it maintains privileged access to international metrology forums, such as the three Consultative Committees for Ionizing Radiation (CCRI) under the International Bureau of Weights and Measures (BIPM).

Participation in these committees not only enables involvement in discussions regarding current technical and scientific developments but also facilitates engagement with leading international laboratories. As evidenced by the Key Comparison Database (KCDB) maintained by the BIPM, the LNMRI holds international recognition for hundreds of measurement processes across relevant physical quantities.

Furthermore, the LNMRI maintains a strong partnership with the International Atomic Energy Agency (IAEA), including its membership in the Secondary Standard Dosimetry Laboratories (SSDL) network.

Given that Brazil possesses a robust infrastructure of laboratories in the field of ionizing radiation—capable of meeting the majority of demands from the productive sector and national institutions—the primary focus of the LNMRI is to maintain national reference standards and ensure metrological traceability for this laboratory network. To this end, it

performs the calibration of reference instruments and provides certified radioactive sources to radiometric analysis laboratories and nuclear medicine services.

Additionally, the LNMRI is responsible for providing Proficiency Testing (PT) for relevant measurement quantities, as there are currently no institutions in the country accredited by Cgcre/Inmetro to perform such activities.

7. DISCUSSION

The ionizing radiation metrological landscape in Brazil presents a unique characteristic that, to some extent, poses an institutional challenge: the National Laboratory for Ionizing Radiation Metrology (LNMRI) is part of the Institute of Radiation Protection and Dosimetry, IRD, a Technical and Scientific Support Organization integrated into the organizational structure of a regulatory body, the National Nuclear Safety Authority (ANSN).

This configuration imposes certain constraints and necessitates specific operational safeguards. Notably, to mitigate potential conflicts of interest and maintain a clear separation between regulatory and metrological functions, the LNMRI must refrain from providing calibration services directly to the regulated sector. In this context, its activities must prioritize the strengthening of the national metrological infrastructure, directing efforts toward supporting the calibration and testing laboratories that serve the regulated industry. Thus, the LNMRI fulfills its role as a national laboratory, ensuring metrological traceability and the reliability of measurements performed nationwide.

This operational model is particularly relevant within the framework of the networks coordinated by CASEC from IRD and INMETRO, specifically the Brazilian Calibration Network (RBC) and the Brazilian Network of Testing Laboratories (RBLE). The laboratories within these networks serve as the operational link between the national standards maintained by the LNMRI and the measurements conducted across the productive sector, including medical, industrial, and research facilities. Consequently, by providing calibration

for the reference instruments used by these laboratories—as well as supplying certified radioactive materials and sources—the LNMRI ensures the dissemination of metrological traceability throughout the entire ionizing radiation measurement chain. This arrangement strengthens the reliability of national measurements and aligns the country's metrological infrastructure with international best practices.

An analysis of the accreditation scopes of laboratories within the CASEC, RBC, and RBLE networks reveals an extensive range of available services. Specifically, there is a broad capacity for measuring radioactivity across various matrices and a significant number of radioisotopes. However, it cannot be asserted that this laboratory infrastructure fully meets the demand for all matrices and radionuclides required by the regulated sector.

Beyond its state mandates by INMETRO designation, the fact that the LNMRI is part of the ANSN structure provides the Authority with a unique competitive advantage. It possesses the most comprehensive metrological infrastructure in Latin America, enabling it to respond swiftly to internal demands for calibration and the production of standard sources, particularly in its capacity as the lead agency for emergency response. Furthermore, this structure allows for proactive planning in the development of metrological processes, ensuring readiness for future regulatory demands arising from technological advancements in the medical and industrial sectors.

8. CONCLUSIONS

The regulation of ionizing radiation activities depends on the reliability of the measurements used to demonstrate compliance with regulatory requirements. In this context, metrology ensures comparability and traceability to the International System of Units (SI), guaranteeing the technical credibility of licensing, inspection, and enforcement processes.

In Brazil, the national metrological infrastructure is structured and aligned with the international system, with the LNMRI serving as the laboratory designated by INMETRO, responsible for maintaining national standards and providing metrological traceability. The network of calibration, testing, and individual monitoring laboratories—integrated into the accreditation networks coordinated by Cgcre/Inmetro and CASEC—constitutes the operational link between national standards and measurements performed in medical, industrial, environmental, and research applications.

Although there is a broad range of services available, there is no evidence that the existing infrastructure fully meets national demand or that the LNMRI is currently capable of providing all necessary traceability. These findings highlight the need for a systematic evaluation of installed capacity and national demand to guide strategic actions for strengthening the metrological infrastructure, thereby ensuring radiological safety, measurement reliability, and the overall effectiveness of the Brazilian regulatory system.

CONTRIBUTORSHIP

Conceptualization: CPG, AECS

Writing – review and editing: CPG, AECS

Note: The authors are retired civil servants from the Institute of Radioprotection and Dosimetry, at the time part of the National Nuclear Energy Commission and, currently, at the National Nuclear Safety Authority.

CONFLICT OF INTEREST

We have no conflicts of interest to disclose.

All authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

The authors declare that the data supporting the results of this study are available in the article. Derived data supporting the conclusions of this study are available upon request from the corresponding author.

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