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Radionuclide metrology: traceability and response to a radiological accident

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ABSTRACT

In the case of a radiological accident, there are characteristic phases: discovery and initial assistance with first aid; the triage and monitoring of the affected population; the release of the affected people; forward the victims to medical care; as well as the preparation of the report on the accident. In addition, studies and associated researches performed in the later period. Monitors, dosimeters and measuring systems should be calibrated by contaminating radionuclide standards. The radioactive sources used must be metrologically reliable. In Brazil, this function is performed by LNMRI/IRD/CNEN, designated by INMETRO, which Radionuclide Metrology Laboratory is responsible for the standardization and supply of radioactive sources in diverse geometries and matrices. This laboratory has a stock of radionuclide solutions with controlled environmental variables for the preparation of sources, which are calibrated and standardized by mean of primary and secondary systems. It is also responsible for the dissemination of standards and, in order to establish the metrological traceability of national standards, participates in international key-comparisons promoted by BIPM and regional metrology organizations. Internally, it promotes the National Comparison Programs for laboratories for the analysis of environmental samples and the traceability for producing centers of

radiopharmaceuticals and Nuclear Medicine Services in the country. The paper presents the demand for ^{137}Cs related to the radioactive accident in Goiania/Brazil and the significant results for the main radionuclides standardized by the Radionuclide Metrology Laboratory for international key-comparisons and national comparisons to provide metrological traceability. With the obtained results, the LNMRI of Brazil integrates the international metrology BIPM network and fulfills its function of supplying, with about a hundred of radioactive standards, the country's needs in different applications, including attendance to radiological accident.

Keywords: Radionuclide Metrology, Radioactive standard sources, Metrological traceability, Response to a radiological accident; 137Cs, Goiania.

1. INTRODUCTION

Radionuclide metrology is the area of the scientific knowledge that studies the radionuclides in their respective radioactive decay-schemes, aiming the elaboration of methods and techniques capable of performing measurements of their radioactivity with the greatest possible precision and accuracy degree. Thus, metrology brings together all the theoretical and practical points of view of the measurement, regardless the uncertainty measurement and the application field, guaranteeing reliability measurements.

To standardize a radionuclide by a primary method means to measure directly all nuclear transitions occurring per unit of time. A complex task, since it involves several parameters such as decay, type of radiation, probabilities and differentiated energy lines. Thus, each radionuclide needs of different measurement techniques and approaches. The metrological culture suggests that the greater the number of standardization methods in a laboratory, the better is the result.

As responsible by dissemination and custody of radioactive standards, the LNMRI must have the greatest number of standardization techniques and methodologies, and thus, ensuring the robustness of the results. The LNMRI has primary methods $4\pi\beta$(PC)-γ(NaI) coincidence based on gas flow proportional counter; $4\pi\beta$(LS)-γ(NaI) anti-coincidence, CIEMAT/NIST and TDCR based on liquid scintillation; peak-sum coincidence based on gamma-spectrometry. In addition, secondary systems measurements: two ionization chambers, IG11 and IG12, to keep the memory of the radionuclide activity values obtained in the primary standardization from key-comparisons promoted by Bureau International des Poids et Mesures (BIPM) of the international metrological chain. It also provides

methods for calibration based on sodium iodide, germanium and lithium for gamma spectrometry and activimeters for radiopharmaceuticals.

LNMRI has a large stock of radionuclide standards to supply national and international users. The radioactive sources in any geometries are prepared by differential weighing in balance of six decimal scales, therefore with a high precision degree and with the guarantee of traceability.

The international metrology vocabulary conceptualizes metrological traceability as the property of a result of measurement or value of a standard to be related to the established references, generally to national or international standards, through a continuous comparison chain, all having established uncertainties. Therefore, a continuous comparison chain is called the traceability chain. The BIPM is at the top of the international metrological chain, so that the measurement capacity of each National Metrology Institute is compiled in a database maintained by BIPM, based on performance obtained in the key-comparisons.

2. MATERIALS AND METHODS

The traceability of the measurements for different radionuclides in primary systems in the LNMRI is obtained by participation in BIPM key-comparisons of the international metrological chain, European Metrology region (EURAMET) and the Asia Pacific Metrology Program (AMPM).

In order to establish the traceability and quality control of the activity measurement in the Brazil, LNMRI has promoted national comparison programs with participants from environmental analysis laboratories (TAUHATA, 2006) and for the radiopharmaceutical production centers and services nuclear medicine services (OLIVEIRA, 2016).

A significant example, it was in the face of the ^{137}Cs accident in Goiania, 1987, with the LNMRI prompt response to the various requests for solid and liquid sources of this radionuclide in its multiple geometries for the calibration monitors and the carrying out of researches.

3. RESULTS AND DISCUSSION

In order to guarantee the traceability of its measurements, the LNMRI participated in the following radionuclide key comparisons promoted by the BIPM: ^{125}I, ^{75}Se, ^{169}Yb, ^{152}Eu, ^{166m}Ho, ^{88}Y, ^{58}Co, ^{89}Sr, ^{65}Zn, ^{32}P, ^{204}Tl, ^{192}Ir, ^{54}Mn, ^{241}Am, ^{139}Ce, ^{55}Fe, ^{131}I, ^{124}Sb, ^{57}Co, ^{67}Ga, ^{177}Lu, ^{59}Fe, ^{99m}Tc,

$^{68}Ge/^{68}Ga$. It also submitted standardized solutions to the SIR/BIPM of the following radionuclides: ^{60}Co, ^{134}Cs, ^{57}Co, ^{152}Eu, ^{133}Ba, ^{139}Ce, ^{131}I, ^{192}Ir and ^{51}Cr. The LNMRI was successful in these comparisons, with its measurements within of the established limits obtained by the average value of the results obtained by the participating laboratories, and only in the of ^{59}Fe comparison the LNMRI result was outlier.

The comparisons for environmental of spiked samples in matrices water, soil, air filter, vegetation and milk were computed from 1991 to 2016 and the number of participants increased from 11 to 29 per year. A total of 32 radionuclides were analyzed, which 16 belonging to the natural U and Th series, plus ^{3}H and ^{40}K. At the beginning of the PNI, 11 laboratories analyzed ^{137}Cs sample and in 2016 this number increase to 15 one, to verify the performance of this radionuclide in this period. In general, the performance of the participating laboratories increased significantly during this period.

The comparisons coordinated and executed by LNMRI for the traceability of radiopharmaceutical producer centers (RPC) as requested by ANVISA, had excellent result for ^{18}F, ^{99m}Tc, ^{131}I, ^{123}I, ^{67}Ga and ^{201}Tl. Similarly, same radionuclides (except ^{18}F) tested in nuclear medicine services (NMS).

The LNMRI supplied a total of 109 ^{137}Cs sources in the period from 1987 to 1990 regarding the Accident of Goiânia for monitoring and researches programs.

4. CONCLUSION

The LNMRI as Brazil's national metrology laboratory is qualified to supply the country's demands in various activity fields, including radiological and nuclear emergency situations, with a high precision and accuracy degree and with the guarantee of the metrological traceability.

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