
METROLOGY LABORATORY OF IONISING RADIATION

Annual Activity Report 2013

UNIT: Radiation Protection and Safety

TEAM

Nome	Category	R&D (%)
Carlos Oliveira	Researcher	100
João Cardoso	Technical	100
Luis Santos	Technical	100
Margarida Caldeira	PhD student, FCT grant	100

OBJECTIVES

- Development of a robust system of primary standards. Ongoing construction of two types of standards: cavity chamber and free air chamber.
- Development and implementation of new methodologies to calibrate the dosimeters for radiodiagnostic namely for conventional radiodiagnostic, for computerized tomography and for mammography in terms the quantities air kerma, air kerma-length product and air-kerma-area products.
- Participation in two European projects of the European Metrology Research Programme (EMRP).
- Participation in activities of EURAMET as Designated Institute namely interlaboratorial comparisons
- Participation in activities of AIEA as SSDL (Secondary Standard Dosimetry Laboratory).
- Participation in activities of EURADOS related to computational dosimetry.
- Maintenance of national standards of dosimetric and radiological protection quantities, characterization of radiation fields and performing the dosimetry of radiation fields.
- Calibration and metrological verification of dosimeters and radiation protection equipment. Irradiation of personal dosimeters for Dosimetry and Radiobiology Group of UPSR and collaboration with RPI-URSN to realize the metrological verification of the radiation protection equipment.
- Improvement of safety radiological conditions at the laboratory and improvement of positioning of equipment to be controlled using a laser system.
- Improvement of the effectiveness of the Quality Management System
- Collaboration with the reviewer team of 43 CMC's available at LMRI and, currently, under revision.
- Ensure representation on international committees and working groups related to the metrology of the ionizing radiation and radiation protection.

MAIN ACHIEVEMENTS

- EMRP IND 04- MetroMetal "Ionising radiation metrology for the metallurgical industry". Start date 01/12/2011. End date 12/01/2014.

During 2013 an n-type HPGe detector with a nominal 52.5% relative efficiency and resolution of 1.9 keV (for 1333 keV Co-60 photons), has been characterized and detector parameters were determined. A model of this detector was created using the MCNP code. Detector parameters were chosen by three different ways: provided by the manufacturer; determined by direct measurements using a set of radiographies taken for this purpose and determined after analysing the results of the

Monte Carlo simulations and comparing them with the experimental results. To validate the model the relative difference between the calculated and experimental full energy efficiencies in the 46.5 – 1332.5 keV energy range should be lower than 5% for two source-to-detector distances. The source is a multi-radionuclide volume source. Two reports were written. The first one about the MC model and the second report about the validation of the model. All partners using different Monte Carlo codes have also written their reports. The IST team have collected all reports and elaborated the final report. The Monte Carlo simulation code used was the MCNP-CP code which is a MCNP-based code created by Andrey Berlizov2 and is able to calculate coincidence summing corrections. The corrections factors were determined by the ratio between the peak area when coincidences were simulated and the peak area when the coincidences were not simulated. Two sources type were used. One type is a multi-radionuclide volume source Pb-210, Am-241, Cs-137 and Co-60. The second type of source is planar sources. The radionuclide is Pb-210, or Cs-137 or Co-60. For the volume source the parameters analysed were the upper dead layer, the lower dead layer, the diameter and the material filling the cold finger, the diameter of the hole where is inserted the cold finger and the distance crystal window. These studies were realized using the same volume multi-radionuclide source as used for the detector characterization and using the same two detector source distances. For the planar sources a study concerning the distance source detector and the diameter of the source has been considered. The sensitivity of the detector efficiency due to the detector, sample and geometry parameter variations was quantified using Monte Carlo simulations. Results allow to know the real impact of variations on some parameters on the final results. Two workshops were organized with the stakeholders and final users. Two abstracts were submitted to an international conference and other two publications are being written.

- EMRP JRP-i13 MetroNORM ‘Metrology for processing materials with high natural radioactivity’. Start date 01/09/2013 end date 31/08/2016. This project has 12 European partners.

The project started in September 2013 with duration of 3 years. Since the beginning of the project a questionnaire to determine currently used devices/systems for measuring the activity of radionuclides in some NORM industries was prepared and sent to the industries. Each partner distributed the questionnaire in its country. Meanwhile IST has participated on a discussion about the reference materials and standard sources to enable accurate and traceable calibrations. Four groups of materials have been chosen and for each group the most important radionuclides have been identified. After that, calibration standards will be developed by the other partners. Concerning the T&E prototype module about NORM and measurement applications to be developed by IST a general scheme of work has been presented. An oral communication in an international conference was presented.

- The characterization of the new model of graphite cavity chamber has pursued, in the framework of a PhD thesis. The electric field inside the chamber was simulated using QuickField. The beam profile of the Co-60 irradiator was measured using a small chamber with a volume of about 1 cm³ and simulated using the BEAMnrc code. Measurements and simulations were made in a 10x10 cm field at 1 m distance from the source. Correction factors have been determined by experimental methods. They will be confirmed by Monte Carlo simulations. The determination of the volume of the chamber will allow to determine the value of the quantity air kerma.
- The implementation of a methodology to calibrate a CT ionizing chamber has been finalized. This methodology encompasses the establishment of the radiation qualities, the dosimetry of these radiation qualities and the methodology of calibration of CT chambers. Special attention is dedicated to the scattered radiation in the edges of the collimators and to the dimension of the radiation beam. Correction factors have been determined. The methodology to calculate the uncertainty of the quantity kerma product length has also been implemented.
- Participation in EURADOS Intercomparison exercise on Monte Carlo modelling for the in-vivo monitoring of Am-241 in Skull phantoms. An intercomparison on in-vivo monitoring for determination of Am-241 in three skull phantoms was launched by EURADOS in 2011. The work focused on the measurement and estimation of Am-241 activity in the human skull. A Monte Carlo

(MC) exercise includes the voxel representations of the real phantoms. The task in this intercomparison was to simulate a specified detector and a well-defined semi-skull phantom. All parameters of the simulation, including photon yield, material property and geometry were fixed. The simulated spectrum agree rather well with the measurement even in the low energy region.

- Two Workshops were organized in the framework of the MetroMetal - Ionizing Radiation Metrology for Metallurgical Industry. The first for the institutional and industrial stakeholders and the second for the general stakeholders and for the end-users. This last workshop has been organized in collaboration with the *Siderurgia Nacional* and with the APOGER (Associação Portuguesa dos Operadores de Gestão de Resíduos e Recicladores) with the support of the EUROPEAN RESEARCH CENTRE FOR RECYCLING.
- In 2013, LMRI participated in the TLD audit to the absorbed dose to water for ^{60}Co promoted by the AIEA. The results obtained for the exercise of 2013 showed a relative deviation of -1.8 %. Agreement within ± 3.5 % is considered satisfactory by the AIEA.

Also a TLD audit for air kerma radiation protection calibrations was done with IAEA and the relative deviation was 1.2 %, with a range of satisfactory results of ± 7 %.

Regarding the Quality Management System one internal audit and one external audit in the framework of the EURAMET and IPAC accreditation, have been carried out. For the internal audit, an external expert was invited from the French metrological laboratory, *Laboratoire National Henri Becquerel* (LNHB).

LMRI provides the community, mainly hospitals, industry, universities, armed forces and IST/ITN Units with calibration and metrological control services. During 2013, 144 dosimeters were calibrated and controlled, 16 medical dosimeters were also calibrated and 200 TLD's were irradiated.

- The LMRI has a representative in the Technical Committee of the Radiological EURAMET, and participates as an observer in the CCRI (I) (Consultative Committee for Ionizing Radiation) of the CIPM (International Committee for Weights and Measures) and is part of the IAEA/WHO SSDL (Secondary Standards Dosimetry Laboratories. Participate also in the Group of Experts of art. 31. (Radiation Protection) of UE.

RELEVANT PAPERS

- Oliveira, C. Carvalho, A. Cardoso, J. and Santos, L., Design, construction and characterization of an irradiator to realize the calibration of the ambient dose equivalent monitors. 16. Congrès International de Métrologie, 05004 (2013). DOI: 10.1051/metrology/201305004. Published by EDP Sciences, 2013. J.-R Filtz, B. Larquier, P. Claudel et J.-O. Favreau (Eds.)
- EURADOS intercomparison exercise on MC modeling for the in-vivo monitoring of Am-241 in skull phantoms (Part I). Tomas Vrba, Pedro Nogueira, David Broggio, Margarida Caldeira, Kevin Capello, Karin Fantínová, Catarina Figueira, John Hunt, Debora Leone, Manohari Murugan, Olaf Marzocchi, Montse Moraleda, Arron Shutt, Soheigh Suh, Masa Takahashim, Katarzyna Tymnińska, Maria Antonia Lopez, Rick Tanner. Radiation Physics and Chemistry (in press).
- Hand monitoring in Fluoro-CT guided procedures. Joana Pereira, João Alves, Miguel Pereira, Augusto Oliveira, João Cardoso, Luís Santos, Sandra Sarmiento, João Santos, Maria José Sousa, Luís Cunha, Anabela Dias, Margarida Gouvêa. In proceeding of: 20th International Conference on Medical Physics (ICMP2013), At Brighton, UK, Volume: Medical Physics International, vol 1, N° 2, 2013, pp 624.

FUNDS

Project/Service	Reference	Timeframe	2013
EMRP IND 04- MetroMetal		01/12/2011-12/01/2014	25,393.63€
EMRP IND 57- MetroNorm		01/09/2013-31/08/2016	45.094,08€
Services		01/01/2013-31/12/2013	58.256,26 €

TEAM RESEARCHERS

NAME: Carlos Manuel Azevedo de Sousa Oliveira

CATEGORY: Principal Researcher (Habilitation)

IST-ID: 14514

ACTIVITIES

Nº	Activity Description	R&D (%)
1	IND04 MetroMetal: Ionising radiation metrology for the metallurgical industry.	30
2	IND57 MetroNORM: Metrology for processing materials with high natural radioactivity.	10
3	Head of LMRI (Metrology Laboratory of Ionising Radiation)	50
4	Education, Training, Conference Organization	5
5	International representations	5
Total		100

WORK SUMMARY

Nº	Work Summary and Main Achievements
1	<p>EMRP Project: IND04 MetroMetal: Ionising radiation metrology for the metallurgical industry. Participants: CIEMAT (Spain), BEV/PTP (Austria), CEA (France), CMI (Czech Republic), ENEA (Italy), IFIN-HH (Romania), IJS (Slovenia), JRC (EC), MKEH (Hungary), NCBJ (Poland), PTB (Germany), SMU (Slovakia and STUK (Finland) and IST (Portugal).</p> <p>The project started in December 2011 with duration of 3 years. During 2013 a n-type HPGe detector with a nominal 52.5% relative efficiency and resolution of 1.9 keV (for 1333 keV Co-60 photons), has been characterized and detector parameters were determined. A model of this detector was created using the MCNP code. Detector parameters were chosen by three different ways: provided by the manufacturer; determined by direct measurements using a set of radiographies taken for this purpose and determined after analysing the results of the Monte Carlo simulations and comparing them with the experimental results. To validate the model the relative difference between the calculated and experimental full energy efficiencies in the 46.5 – 1332.5 keV energy range should be lower than 5% for two source-to-detector distances. The source is a multi-radionuclide volume source. Two reports were written. The first one about the MC model and the second report about the validation of the model. All partners using different Monte Carlo codes have also written their reports. As one of our task we have collected all reports and elaborated the final report. Two workshops were organized with the stakeholders and final users. Two abstracts were submitted to an international conference and other two publications are being written.</p>
2	<p>EMRP Project: IND57 MetroNORM: Metrology for processing materials with high natural radioactivity. Participants: CEA (France), CIEMAT (Spain), CMI (Czech Republic), ENEA (Italy), IJS (Slovenia), IST/ITN (Portugal), JRC (EC), MKEH (Hungary), NPL (UK), NRPA (Norway), SMU (Slovakia) and STUK (Finland).</p> <p>The project started in September 2013 with duration of 3 years. Since the beginning of the project a questionnaire to determine currently used devices/systems for measuring the activity of radionuclides in some NORM industries was prepared and sent to the industries. Each partner distributed the questionnaire in its country. This phase is still running. Meanwhile IST has participated on a discussion about the reference materials and standard sources to enable accurate and traceable calibrations. Four groups of materials have been chosen and for each group the most important radionuclides have been identified. After that, calibration standards will be developed by the other partners. About the T&E prototype</p>

	<p>module about NORM and measurement applications to be developed by IST a general scheme of work has been presented. An oral communication in an international conference was presented.</p>
3	<p>Management</p> <p>Head of LMRI (Metrology Laboratory of Ionising Radiation)</p> <p>The LMRI is the laboratory recognized by IPQ, the National Institution for Metrology, as the national laboratory for ionizing radiation. LMRI has its Calibration and Measurements Capabilities (CMC's) recognized by CIPM (International Committee for Weights and Measures) and published in the BIPM site and ensures international traceability of national standards for dosimetric quantities upon compliance with the requirements of the MRA (Mutual Recognition Arrangement). An annual audit is done to the LMRI and the results are presented on the Quality Technical Committee (TC-Q) of EURAMET. This year the annual audit has been realized by an expert of Henry Becquerel Laboratory. Additionally, this year (Mars 2013) the QS of the period of the last 4 years has been positively re-evaluated in the framework of TC-Q of EURAMET. As results of the audit, it was recognized that Quality System of the institute is adequate and its implementation demonstrates the conformity with the requirements of CIPM-MRA". LMRI has had yet an audit for accreditation on two techniques H*(10) ambient dose equivalent and Hp(10).personal dose equivalent. Concerning the legal metrology, LMRI as Metrological Verification Body - OVM recognised by IPQ, has had an audit in this framework.</p> <p>LMRI has participated in inter-laboratorial comparison: (i) IAEA TLD POSTAL DOSE QUALITY AUDIT for 60Co / Absorbed dose water; (ii) EURAMET project No. 1132 – EURAMET supplementary comparison of the ambient dose equivalent rate for photon radiation and (iii) IAEA TLD POSTAL QUALITY AUDIT1 for 137Cs radiation protection calibrations.</p>
4	<p>Services</p> <p>LMRI provides the community, mainly hospitals, industry, universities, armed forces and ITN Units with calibration and metrological control services. This metrological control of instruments is being carried out under a contract with Portuguese Institute of Quality and is the enforcement of <i>Portaria n.º 1106/2009</i>, dated September 24th. During 2013 were calibrated and controlled 163 dosimeters and radiation protection monitors and 16 TLD dosimeters were irradiated. For the Dosimetry and Radiobiology Group of UPSR 260 TLD dosimeters were irradiated and the metrological control of installed detectors and associated instrumentation of the RPI (URSN) radiological protection system were realized. Also for Radioprotection and Radioactive Waste Group, LMRI realizes calibration of several equipment.</p> <p>This year the total amount due to the services done to the exterior has been of 58.256,26 €. The costs of the internal calibrations are estimated around 10.834,58 €.</p>
5	<p>Supervision of Theses</p> <p>PhD thesis "Design, construction, calibration and inter-laboratorial comparison of an air-kerma cavity standard" Margarida Isabel Camacho Caldeira. IST. Co-supervisors: Jean Marc Bordy (LNHB, CEA) and Lidia Ferreira. (2009-....).</p> <p>Workshops</p> <ul style="list-style-type: none"> • Workshop "Project EMRP: IND04 MetroMetal "Ionizing Radiation Metrology for Metallurgical Industry". CTN-IST. 3 de Abril 2013. • Workshop "Project EMRP: IND04 MetroMetal "Ionizing Radiation Metrology for Metallurgical Industry", for stakeholders and end-users. CTN-IST. December, 6th 2013.
6	<p>National Representations</p> <p>Member of the Group of Experts referred to in Article 31 of Euratom Treaty (Radiation Protection).</p> <p>Corresponding Member of the Working Party on Implications on Health and Safety Standards established under Article 31.</p> <p>Official Observer of the Consultative Committee for Ionizing Radiation Section I (X and γ-Rays, charged particles) of International Committee for Weights and Measures (CIPM).</p> <p>Contact person of the EURAMET- European Association of National Metrology Institutes.</p> <p>Participation on Working Group activities of EURADOS-European Radiation Dosimetry</p>

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PUBLICATIONS

- C. Oliveira, A. Carvalho, J. Cardoso and L. Santos, Design, construction and characterization of an irradiator to realize the calibration of the ambient dose equivalent monitors. 16. Congrès International de Métrologie, 05004 (2013). DOI: 10.1051/metrology/201305004. Published by EDP Sciences, 2013. J.-R Filtz, B. Larquier, P. Claudel et J.-O. Favreau (Eds.).

COMMUNICATIONS

- C. Oliveira, “Apresentação do projecto MetroMetal. A metrologia na indústria e suas ligações com a saúde e o ambiente”. Workshop “Project EMRP: IND04 MetroMetal “Ionizing Radiation Metrology for Metallurgical Industry”. CTN-IST. 3 de Abril 2013.
- C. Oliveira, “O Programa EMPIR (European Metrology Programme for Innovation and Research) para a próxima década. Workshop “Project EMRP: IND04 MetroMetal “Ionizing Radiation Metrology for Metallurgical Industry”. CTN-IST. 3 de Abril 2013.
- C. Oliveira, “Metrologia na Ciência e Desenvolvimento” 1^a. Edição do SPQ EXPO - Fórum e Exposição de Normalização, Metrologia e Qualificação. Organização Instituto Português da Qualidade e Associação Portuguesa para a Qualidade e Associação Empresarial de Portugal/EXPONOR. 26 e 27 Setembro 2013. Porto.
- C. Oliveira, “A metrologia da radioactividade na indústria metalúrgica”. Workshop “Project EMRP: IND04 MetroMetal “Ionizing Radiation Metrology for Metallurgical Industry”. CTN-IST. 6 de Dezembro 2013.
- C. Oliveira, “MetroMetal and MetroNorm: EMRP-funded Joint Research Projects. Meeting of the Group of Experts referred to in Article 31 of the Euratom Treaty. Luxembourg, 19-20 November 2013.
- O. Pellegrino, I. Godinho, C. Oliveira, E. Filipe, SI physiological Units. 16. Congrès International de Métrologie. 7-10 October 2013. Paris.
- C. Oliveira, A. Carvalho, J. Cardoso and L. Santos, Design, construction and characterization of an irradiator to realize the calibration of the ambient dose equivalent monitors. 16. Congrès International de Métrologie. 7-10 October 2013, Paris.
- I. Paiva, M. Reis, L. Portugal, C. Cruz, C. Oliveira, Establishing an E&T platform on NORM related industries, Nuclear Education and Training, NEST’et November 2013. Madrid.

EDUCATION

- Supervisor, PhD Thesis, *Design, construction, calibration and inter-laboratorial comparison of an air-kerma cavity standard*, by Margarida Isabel Camacho Caldeira, Instituto Superior Técnico. Universidade de Lisboa (running).

PROJECTS

- IND04 MetroMetal: Ionising radiation metrology for the metallurgical industry. *EMRP Project* Leading Institution: Ciemat, Spain. Coordinator of Portuguese team: C. Oliveira. From December 2011 to December 2014.
- IND57 MetroNORM: Metrology for processing materials with high natural radioactivity. *EMRP Project* Leading Institution: BEV, Austria. Coordinator of Portuguese team: C. Oliveira. From September 2013 to August 2016.

CONTRACTS

Estatísticas dos serviços prestados em 2013 (LMRI)			
Serviço para o exterior			
Tipo de análise/ensaio/serviço	Unit Cost	QTY	Income (without VAT)
Calibração de câmaras de ionização	1.169,00 €	16	18.704,00 €
Verificação de dosímetros de área portáteis (radiação Gama)	378,81 €	85	32.198,85 €
Verificação de dosímetros de área (radiação X)	568,22 €	2	1.136,44 €
Verificação de dosímetros de área (neutrões)			- €
Verificação de monitores de contaminação	378,81 €	7	2.651,67 €
Verificação de dosímetros individuais (radiação Gama)	189,41 €	10	1.894,10 €
Verificação de dosímetros individuais (radiação X)	284,10 €	5	1.420,50 €
Verificação de dosímetros de área fixos (radiação Gama)			- €
Irradiação de TLD's		5	250,70 €
	Partial Total		58.256,26 €
Serviços Internos (CTN - UPSR e URSN)			
Receita não cobrada			
Calibração de câmaras de ionização			- €
Verificação de dosímetros de área portáteis (radiação Gama)	378,81 €	12	4.545,72 €
Verificação de dosímetros de área (radiação X)			- €
Verificação de dosímetros de área (neutrões)	378,81 €	2	757,62 €
Verificação de monitores de contaminação	378,81 €	5	1.894,05 €
Verificação de dosímetros individuais (radiação Gama)	189,41 €	13	2.462,33 €
Verificação de dosímetros individuais (radiação X)			- €
Verificação de dosímetros de área fixos (radiação Gama)			- €
Irradiação de TLD's	391,62 €	3	1.174,86 €
	Partial Total		10.834,58 €
	TOTAL		69.090,84 €

SCIENTIFIC COMMITTEES

- *Member of the Group of Experts referred to in Article 31 of Euratom Treaty (Radiation Protection).*
- *Corresponding Member of the Working Party on Implications on Health and Safety Standards established under Article 31.*
- *Official Observer of the Consultative Committee for Ionizing Radiation Section I (X and γ -Rays, charged particles) of International Committee for Weights and Measures (CIPM).*
- *Contact person of the EURAMET- European Association of National Metrology Institutes.*
- *Participation on Working Group activities of EURADOS-European Radiation Dosimetry Group.*