Metrology Laboratory of Ionizing Radiation

Carlos Oliveira

This year it was signed a new collaborative protocol between the ITN and the IPQ, replacing the former, dated from 1989, and stepping up forms of cooperation between the ITN and IPQ to consolidate responsibilities and common interests in scientific, legal and applied metrology, in the field of ionizing radiation.

The implementation of the national standards requires capabilities for research and development of technology to enable the traceability of the metrological chain in the country. The protocol recognizes that the ITN through LMRI had continued for almost 20 years activities leading to that goal.

It is also to be notted that, for the first time and by decision of the BIPM, and proposal of IPQ, the ITN has now an Observer Status in the Consultative Committee for Ionizing Radiation-Section1.

The Metrology Laboratory of Ionising Radiation (LMRI) had been actively involved in activities related to the scientific, applied and legal metrology. Due to the reduced number of the people assigned to LMRI much of the new developments and research activities have been realized under master thesis.

LMRI continue to participate in European project in the framework of the EURAMET organization: "Increasing cancer treatment efficacy using 3D brachytherapy". This project arises from the implementation of the "European Metrology Research Programme" (EMRP) and is co-funded by the European Commission.

A new characterization of the diagnostic radiation qualities according to the International Standard IEC 61267 has been performed with success.

A methodology for the optimization of the Ionizing Chambers (IC) for the direct measurement of the *H*p(10) had been developed and results of a set of 3 IC were compared.

Simulation studies in order to develop the shielding and the irradiation system for a ^{241}Am-Be neutron source of 37 GBq has been done.

The collaboration with other ITN research teams continued, namely with Dosimetry and Radiobiology Group (GDR) at UPSR and with Radiation Technology Unit (UTR). Technical assistance has been assured to the RPI during its annual maintenance. The collaboration with outside Researcher Groups has been pursued namely with Instituto Nacional de Saúde Dr. Ricardo Jorge (INSA) and Faculdade de Farmácia - Universidade de Lisboa (FF-UL).

Special attention has been devoted to the collaboration with the University. The LMRI has collaborated with FCT – UNL (Faculdade de Ciências e Tecnologia - Universidade Nova de Lisboa -) and as a result of that, five master theses have been concluded and four already approved.

Meanwhile other two master theses were accepted by the university to be performed at the LMRI during the next year.

Concerning the legal metrology 156 dosimeters were calibrated and about 1200 TLD's dosimeters were irradiated.

The Quality System, essential in the LMRI namely to maintain the CMC's (Calibration and Measurement Capabilities) in order to participate in Mutual recognition Arrangement (MRA) of the International Committee of Weights and Measures (CIPM), under the authority given to it in the Metre Convention has been maintained. A IAEA/WHO TLD postal dose quality audit for radiotherapy level dosimetry has been performed. The results are considered satisfactory.

One of the members of the team (LS) participates as Quality Manager of the UPSR QS in the Accreditation process which involve the UPSR, also give support to management of the Data Base of the Environmental Radioactivity Group.

Members of the Group participate as observers on the CCRI(I) meetings of BIPM and are involved in several committees from other organisations like the Contact Person in the Ionising Radiation Technical Committee of EURAMET, Computational dosimetry group of EURADOS, ASTM sub-committee E10.01 and Group of Experts of art. 31 (Radiation Protection).

Research Team

Researcher
C. OLIVEIRA, Princ.

Technical Personnel
J. CARDOSO, graduated technician
L. SANTOS, (50%)

Fellow
A. CASTRO, technician ITN consultancy contract

Calculation of Uncertainties Associated With Variations In Geometry Of Seeds Used In Brachytherapy

Milton Rodrigues[1], João Cardoso, Luís Portugal and C. Oliveira

Objectives

This work is inserted in the jointly European research project T2-J06: "Increasing cancer treatment efficacy using 3D Brachytherapy, co-financed under the project iMERA-Plus according to Grant No. 217257 from the European Commission and EURAMET. The aim of this project is to create a primary standard for measuring absorbed dose in water, D_W, and reduce the uncertainty of dose deposited in a target volume, making it comparable with the current uncertainty in external radiotherapy.

Results

In this work dosimetric quantities were calculated as described in TG-43 (1) of the AAPM using Monte Carlo simulations for a brachytherapy seed currently available in the market and evaluated the influence of geometric approximations to the true geometry of the seed. A sensitivity study was performed in order to investigate the uncertainty in dose due to manufacturing tolerances of seed.

Seed EchoSeed 6733 shown in Figure 1 is a seed of Iodine-125 adsorbed on silver cylinder putted inside a titanium tube "threaded" like a screw with 6 "threads". There are 2 published studies (2, 3) on the seed using two different Monte Carlo codes.

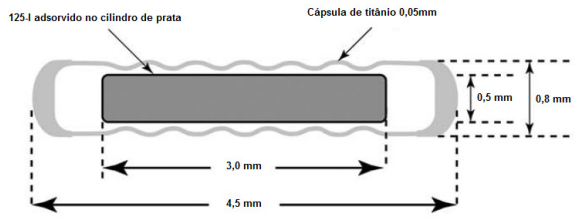


Fig.1 EchoSeed 6733.

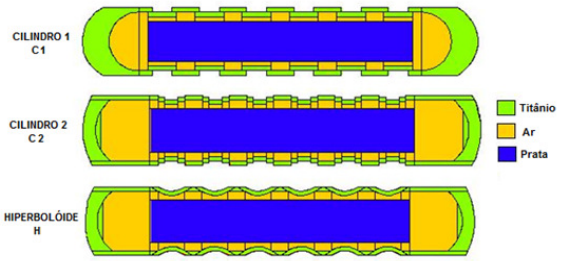


Fig.2 Representation of the three geometries used in this work to model the seed EchoSeed 6733 and their respective materials.

Both authors modeled the body of the seed with a set of drums, and their ends with two spheres of different radii and centers. The effect of this type of approach has been studied in this work, through the use of three different geometries to represent the seed (see figure 2). All seeds were simulated in a spherical water phantom with a radius of 15cm

Using the Monte Carlo method the radial dose function for 16 different radial distances between 0.1 cm and 10 cm for the 3 different geometries have been calculated. Uncertainties lower than 0.1% for radial distances up to 1cm and uncertainties below 0.5% to 16 radial distances between 1 and 10 cm were achieved. The results revealed that there is a good agreement between the radial dose functions of the 3 geometries.

2D anisotropy function, for the 3 geometries, for 10 radial distances up to 7 cm have been calculated with a statistical uncertainty lower than 2%. The results obtained show good agreement between the values for the several geometries, except for the region between 0 º - 20º.

The tolerances in the manufacturing process of the seed EchoSeed 6733 are not known so accurate, especially in terms of their ends. However, the 6711 seed has a structure very similar to the seed of this study; the manufacturer is the same and used the same materials. These facts support the view that these seeds have approximately the same uncertainties of manufacture.

It was also considered that variations on possible thicknesses for the ends of each seed follow a rectangular distribution. For tolerances of ±0.05mm at the ends uncertainties of 6% and 2% in the dose calculated, for radial distances of 0.25 cm and 1 cm and polar angles of 0º, was obtained; for the same radial distances and for the polar angle of 10º, uncertainties are 3% and 1.5%, respectively, has been achieved.

References

Rivard, M. J., Coursey, B. M., DeWerd, L. A., Huq, M. S. Ibbott, G. S., Mitch, Nath, R., Williamson, J. F. Update of AAPM Task Group No. 43 Report: A revised AAPM protocol for brachytherapy dose calculations. Medical Physics 2004; 31: 633–674.

Sowards, K. Meigooni, A.S. A Monte Carlo evaluation of the dosimetric characteristics of the EchoSeed Model 6733 125I brachytherapy source, Brachytherapy, 2002; 1: 227-232.

Taylor, R.E.P., Rogers, D.W.O., An EGSnrc Monte Carlo-calculated database of TG-43 parameters, Medical Physics 2008; 35: 4228-424.

[1] FCT-UNL

Comparative study of three ionization chambers for measurement of Hp(10) and a methodology for its optimisation

H. Silva[1], J. Cardoso, C. Oliveira

An ionization chamber (IC) which directly measures the quantity personal dose equivalent, *H*p(10), can be used as a secondary standard in metrology laboratories. Ideally, these chambers used for the direct measurement of *H*p(10) should be independent of the radiation energy and angle of incidence, since at the metrology laboratories some spectral differences can be found for the same radiation quality. The goal of this work is to design an IC as independent as possible of the radiation energy and of the radiation incidence angle. Two ionization chambers were constructed. The responses of these chambers were investigated together with the response of an existing chamber. The differences between them are the size of the backscatter block, the dimension of the active volume and the frontal plate of the chamber. The response of the three chambers were experimentally investigated as a function of the radiation energy and the incidence angle, using the X-ray radiation qualities of the narrow spectral series and the gamma radiation of ^{137}Cs, described in the ISO 4037–1 standard, and the incidence angle of 0°, 45°, 60° e 75° with normal. The three chambers were studied using Monte Carlo simulations in order to understand the main physical processes related to the energy deposited. It was verified that the ratio between the energy deposited (E_{dep}) in the active volume calculated by Monte Carlo and the charge collected by the chamber (experimental values), shows the same type of energy dependence for the three chambers. Based on the calculations of the deposited energy performed by MC simulation and on the universal behavior of the ratio E_{dep} /Q, it is possible to obtain a prediction of the collected charge for each particular chamber. Applying the relationships established on the theoretical approach it becomes possible the design of a optimized ionization chamber for the direct measurement of $H_p(10)$.

[1]FCT-UNL

Characterization of Diagnostic Radiation Qualities at LMRI according to International Standard IEC 61267

P. Limede[1], J. Cardoso, C. Oliveira

The purpose of this study was to determine and characterize several qualities of radiation, according to IEC 61267, in order to be used in the metrological control of dosimeters used in diagnostic radiology. In this study, the international standard IEC 61267 which uses the determination of the half-value thickness (HVL) to characterize the different qualities of radiation has been used. Besides HVL, this standard refers two other parameters, and they are the homogeneity coefficient - *h* and the ratio y (1º HVL) / y (0). Prior to the characterization of diagnostic radiation qualities RQR (without attenuation), RQA (with attenuation) and RQT (TAC), it was necessary to characterize the profile of the radiation field and to determine the inherent filtration of the X-ray ampoule. The process to characterize the radiation qualities was to determine the additional filtration of aluminum needed in order to obtain values of HVL, *h* and the ratio above referred required in the standard. For all qualities of radiation it was still considered the calculation of the uncertainty of the HVL based on the fitted exponential function. The results satisfy all the criteria set by the standard, so it can be concluded that radiation qualities of RQR, RQA and RQT are properly characterized.

[1]FCT-UNL

Project of an irradiation system for a ^{241}Am – Be source

C. Santos[1], C. Oliveira

The purpose of the work is the development of an irradiation system for a ^{241}Am – Be source of 37 GBq. When the source is not in the irradiation position the irradiator must assure an efficient radiological protection which means that the dose at the contact should be smaller than 20 mSv in a year (<10 µSv/h). The configuration of the irradiator is cylindrical. The study of the materials was based on the determination of the neutron (thermal, epithermal and fast) and photon (primary and secondary) fluxes and its variation with the distance to the source using Monte Carlo simulation methods. Considering the several factors, physics and economics ones, the main material chosen for the shield was the polyethylene. Based on the results obtained, the final prototype of the irradiation system has a polyethylene cylinder with 35 cm of radius and 40 cm of height, involved by a sleeve of concrete with 6 cm of thickness. The source is located 10 cm from the bottom. The cylinder must have a central hole with 3.8 cm of diameter and 31.6 cm length (where the source can pass) from the top and a second hole with 1 cm of diameter that extends from the bottom to the end of the first hole allowing the passage of the elevation system of the source. To this structure is associated a fixed cover of concrete with 6 cm height and two removable covers of polyethylene. The maximum value of ambient dose equivalent at the contact is 8.5 µSv/h.

[1]FCT-UNL

Dose mapping around radiation devices used in industry: a tool for radiation protection purposes

R. Costa[1], C. Oliveira

Radiological instrumentation used in industry uses radiation emitted by radioisotope sources or by X ray tubes. A detailed study has been done concerning the characterization of the radiation field around the radiation devices namely its dose mapping based on Monte Carlo simulations. The dose evaluation is based on the operational quantity ambient dose equivalent, *H**(10). The equipment studied were a (*i*) moisture and density gauge a (*ii*) level gauge, and a (*iii*) irradiation devices used in gammagraphy. The radiological risk of this last type of equipment is considered the highest among the several radiological devices used in industry and are the ones where the probability of occurring accidents is higher. For the moisture gauge, with the source in air, it was possible to verify larger doses in planes perpendicular to the steel tube where the source is contained, which can be particularly harmful to the user. When the gauge is collecting data and the source is immersed in soil the user wait for the end of the collecting process close to the gauge. The dose is rather smaller if the user is positioned 1 m far from the gauge. In the dose mapping for the level gauge was observed a strong collimation. Around the container there are areas with high and low doses, making the establishment of controlled and/or supervised zones of great importance, allowing the workers to avoid areas with higher doses. During a gammagraphy analysis the definition of controlled zones are of extreme importance as is well seen in the dose mapping obtained for the scenario studied. The material, dose mapping, obtained in this work can be used for several applications namely helping to identify good and bad practices and to define controlled or supervised zones.

[1]FCT-UNL

Quality System

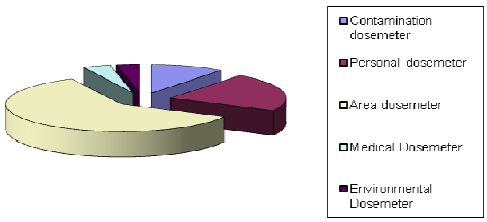
L. Santos, J. Cardoso, C. Oliveira

To meet the requirements of the NP EN ISO/IEC 17025:2005, the quality system deserved, once again, all attention. The Metrology Laboratory of Ionizing Radiation (LMRI) submitted for accreditation two techniques in metrological control of radiation protection monitors in terms of the operational quantities, personal dose equivalent, Hp(10), and ambient dose equivalent, H*(10), according to the standards IEC 61344, IEC 61526 and IEC 60846, respectively.

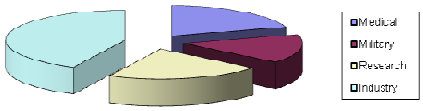
Services

L. Santos, J. Cardoso, A. Castro, C. Oliveira

The calibration services are our more visible activity, providing to the community, mainly for industry, universities, hospitals, armed forces and departments of ITN, services of metrological control. This metrological control of instruments for measurement of ionising radiation is being carried out under a contract with Portuguese Institute of Quality and is the enforcement of Portaria nº. 1106/2009 dated of 24 of September. During 2009 were calibrated 156 dosemeters. The following figures can quantify the work done in this particular area.



Instruments calibrated by users activity



Instruments calibrated by type of use

External Services

LMRI collaboration with INSA group

The collaboration with INSA (National Institute of Health), in the field of radiobiology, continues. This year, mainly with lymphocyte irradiations of human blood, with gamma radiation from the Co-60, for cytogenetic diagnostic purposes for the pathology ataxia *telangiectasia*.

LMRI collaboration with FF-UL group

This work aims to study the potential effects of novel radioprotectors, namely manganese (III) porphyrins with catalytic antioxidant activity, against radiation-induced genotoxicity. To achieve this goal, human lymphocytes from healthy donors have been submitted to low LET radiation (60Co-γ rays), in the presence or absence of the compounds under study.

Internal Services

LMRI collaboration with ITN Groups

Unit of Reactors and Nuclear Safety (URSN)

The LMRI performs, every year, in the RPI maintenance period, the metrological control of installed detectors and associated instrumentation of the RPI radiological protection system. This includes the hand-foot contamination monitor, MAB HFM 2102; the area monitors measuring system MGP C/EIP 51 with five ionization chambers; the area monitors measuring system Automess 632.1 with four Geiger-Muller detectors; the fission products detection system, Tracerlab, Inc. MWP-1A; the Iodine detection system, AIEA AIRMON; two, alpha and beta radiation detection systems in aerosols, ABPM201L; detection system for beta radiation on samples or filters, ECM21+BCF31; iodine detection system, IM201S; and, also, metrological control of fourteen personal electronic monitors, three area monitors and one contamination monitor.

Dosimetry and Radiobiology Group

In 2009 about 1200 TLD dosemeters have been irradiated for UPSR individual dosimetry group. About 700 for Hp(10) and about 300 for Hp(0.07).
In collaboration with other groups, the cells and blood irradiation for the UPSR radiobiology and dosimetry group has been one of the most important collaboration. The purpose of the work was the establishment of a dose response curve for biological dosimetry, using lymphocytes from human peripheral blood from healthy donors for both gender and different age group. The dose range studied is from 0.0Gy to 3.0Gy using a source of ^{60}Co. About 60 irradiations have been carried out.

Environmental Radioactivity Group

The technical support to UPSR - Environmental Radioactivity group database (SEAC) and the data submission for the Radioactivity European Measurement Database (REM) has been made by a LMRI technician (LS). For data submission to REM, first it's necessary the treatment of the SEAC values in an access database, export this files to "tab delimited file" format and after this submit them to REM.