

Dosimetry and Radiobiology

Pedro Vaz and Berta Martins

During 2008, a reorganization of the activities of the UPSR in the areas of Dosimetry and Radiobiology was implemented, in order to fully exploit the synergies of the competences held by the researchers and technicians and to address in a more efficient way the cross-cutting and transversal scientific issues that characterize modern Dosimetry and Radiobiology. As such the Dosimetry and Radiobiology Group (GDR) was created.

The main components of activity are Individual and Environmental Dosimetry, Computational Dosimetry, Internal Dosimetry, Biological Dosimetry and Radiobiology. Special emphasis was devoted to the expansion of the activities in the area of Radiobiology and Internal Dosimetry. Several laboratories were re-activated and the Whole Body Counter was brought back into operation, after several years of halting state. Activities in the area of Biological Dosimetry regained intensity. Computational Dosimetry is an area of competence of the GDR, namely in Monte Carlo simulations for modelling radiological installations involving the operation of radiation or radioactive sources and particle beams in the medical and industrial sectors and for assessing the exposure of professionals in medical practices.

Researchers and fellows from the GDR have:

- Participated in several R&D projects conducted by international consortia, either in the framework of E.U. 6th and 7th Framework Programmes or in collaboration with CERN,
- Submitted research projects to the Portuguese Foundation for the Science and Technology,
- Participated in the submission, by international consortia, of projects to the E.U. 7th Framework Programme,
- Participated in intercomparison exercises in the field of Individual and Environmental Dosimetry organized in the framework of the activities of EURADOS.

As for the services, the GDR kept maintaining the UPSR individual dosimetry monitoring services, the Central Dose Registry and performed the safety assessment of complex radiological installations (radiotherapy vaults and nuclear medicine services).

A special effort was undertaken in order to increase the preparedness of response of the GDR in the context of retrospective dosimetry studies in radiological emergencies or following overexposures to ionizing radiation. The need to assess the doses and to reconstruct retrospectively the sequences leading to such situations (emergencies, overexposures), requires

competences in areas such as Physical Dosimetry (measurements), Internal Dosimetry (using biokinetic models and involving modelling issues), Computational Dosimetry (Monte Carlo modelling and simulations) and Biological Dosimetry (cytogenetic studies, amongst others). Four fellows were hired to help developing the GDR's scientific competences in these areas. Several protocols of response to emergencies were implemented.

Medical applications of ionizing radiations are also recognized as an area of great potential and several activities were undertaken: the GDR researchers participated in the preparation and submission of R&D projects to the E.U. 7th Framework Programme, to the Portuguese Foundation for the Science and Technology (FCT). Collaborative links with hospitals and clinics were fostered. Several Master thesis in topics associated to Radiology, Nuclear Medicine and Radiotherapy were accomplished, under the supervision of researchers of the GDR.

The radiobiology of low doses of ionizing radiation is currently a priority in scientific research of the biological effects of radiation due to the uncertainties that remain about the mechanisms of response of cells, tissues and biological systems in the range of low doses, and the implications that the study of low doses can have in different areas of application, including the radiation protection of individuals exposed occupationally or environmentally, or the use of ionizing radiation in medical diagnosis or therapy. Researchers of the GDR are developing several lines of investigation in this area, in collaboration with R&D consortium partners and stake-holders, including hospitals, occupational medicine service providers and academic institutions. The GDR promoted the organization of the LOWRAD 2008 Conference in Lisbon, in November 2008. This event was a major and most successful gathering of experts worldwide, on the effects of low doses of radiation.

Several researchers maintained regular collaborations with several Portuguese universities and higher education institutions, teaching Radiation Protection- and Dosimetry-related disciplines in the framework of graduation and Master programmes and supervised several graduation, master and Ph.D. theses.

Last but not least, researchers from the GDR acted as national representatives in Committees and Working Groups under the auspices of the IAEA and the OECD Nuclear Energy Agency and provided consultancy to the drafting of legislation and regulations.

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EU-Trimer: preparation of the European technical recommendations for monitoring individuals occupationally exposed to external radiation.

J.G. Alves, P. Ambrosi¹, D. Bartlett², L. Currivan³, J.W. van Dijk⁴, E. Fantuzzi⁵, V. Kamenopoulou⁶

The aim of this project is to prepare the European technical recommendations for monitoring individuals occupationally exposed to external radiation. It is a two-year project funded by the European Commission, Directorate-General Energy and Transport, under contract TREN/07/NUCL/S07.70121. This work is also being developed in the framework of the activities of Eurados working group 2 (WG2) on *Harmonization of Individual Monitoring in Europe*.

An initial draft version_1.1 was presented and discussed at the Eurados annual meeting held in January 2008. Following the inputs and comments received thereafter (giving rise to v1.2 and v1.3), draft Version_1.4 was disseminated in August 2008 to the Eurados extended WG2 members, European and international organizations such as IAEA, IEC, ISO, ICRU, ICRP, ESOREX, EUROMET and EAN. The network of contact persons was considered crucial to the success of the project providing inputs from relevant national organizations like radiation protection authorities, individual monitoring services, calibration laboratories from EU Member States, as well as candidate and associate States. In total 94 institutes and 9 organizations were contacted asking for comments on the draft. Responses were received from 17 countries and 5 organizations. The collected information was analysed at the Athens meeting in November and version 2.1 was produced and disseminated for further discussion at the next Eurados annual meeting to be held in January 2009.

¹ PTB, Germany;

² formerly HPA, UK;

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Assessment of the cosmic radiation dose received on military transport flights

P.L. Melo, J.C. Mairos¹, J.G. Alves

The main objective of this study was to estimate using computer simulations the annual dose arising from cosmic radiation exposure, incurred by aircraft crew members in military transport missions. The study was performed based on realistic flight profiles carried out by the Squad 501 of the Portuguese Air Force (FAP) from Base Aérea n. 6 (Montijo), and special concern was dedicated to the pregnant aircraft crew member. In order to meet the objective, the air routes of two crew members that flew most during 2006 were considered in the simulations, and the expected variations of the flight levels' altitude reported by FAP were taken into consideration. Besides this approach, in order to obtain a realistic annual dose variation representative of the Squad's exposure, the simulations were carried out considering the combined effects of the solar cycle's influence, as well as the expected flight levels variations. The simulations were performed using the EPCARD v3.3 and CARI-6 computing codes, in terms of the effective dose and the ambient dose equivalent quantities.

Nearly all the flights performed in 2006 were simulated and the exceptions account for less than 1% of the annual dose. In 2006 nearly 45% of the total dose was received in routes performed in the NW quadrant. The annual dose received in 2006 for the reported flights was 535 μ Sv for crew A and 560 μ Sv for crew B. These values may vary by as much as 110 μ Sv due to the ± 2.000 ft expected variation of the flight profile. The worst case scenario was assumed taking into consideration the same flights performed in conditions of solar minimum combined with the highest flight level. In this case, the expected annual dose was found to be 685 and 713 μ Sv, respectively for crew A and B. Even if a 30% uncertainty is considered the values obtained are below (or at) the annual dose limit for members of the public. Based on the flights performed in 2006, the aircraft crew of Squad 501 should not be considered as exposed workers. It was further recommended that if in the forthcoming years the flights performed differ considerably from the ones analysed a similar exercise should be carried out.

This work is developed under a collaboration project with the Centro de Medicina Aeronáutica da Força Aérea Portuguesa, and aims at the evaluation of the cosmic radiation dose received by military aircraft crew in transport missions using simulation programs. The EPCARD software is used under a licence agreement from the Institute of Radiation Protection of the Helmholtz Zentrum Munchen, German Research Centre for Environmental Health (formerly GSF).

¹ Centro de Medicina Aeronáutica da Força Aérea Portuguesa

Dose response curve for biological dosimetry

V. Martins, O. Monteiro Gil

The aim of this study is to establish the first dose-response curve for biological dosimetry for low level radiation exposure at ITN. This can be used for the evaluation of dose exposure in case of radiological accident or a terrorist attack. The doses chosen for this work ranged from 0.0Gy to 3.0Gy from a ⁶⁰Co radioactive source from LMRI, and the study was equally performed in individuals according to sex and age groups.

We have already completed the implementation and validation of cytogenetic analysis protocols, the questionnaire and the informed consent for the study population, according to NP EN ISO 17025, for the future accreditation of the cytogenetics lab. Our preliminary results are already being analyzed.

Thyroid Cancer: Genetic and cytogenetic characterization of a patient's population

O. Monteiro Gil

The individual genetic susceptibility associated with thyroid carcinoma was investigated by assessing the polymorphisms of genes involved in biotransformation (*GSTT1*, *GSTMI*, *GSTP1*) and genes involved in the repair of DNA damage (*ERCC2*). The combined genotypes *GSTMI**0, *GSTT1**0, *GSTP1* Ile/Ile result in a significant increased risk for papillary cancer (PC), but not for follicular cancer (FC). For the *ERCC2* gene namely for polymorphisms Asp312Asn and Lys751Gln, we observed that individuals homozygous for both genotype variants have greater risk for developing papillary cancer.

The cytogenetic study on the possible chromosomal instability present in these patients (chromosomal aberrations and micronuclei), by comparison to a control group, showed no significant differences between both groups. Patients with thyroid PC and FC are treated with iodine-131 after total thyroidectomy, a therapy with great clinical success. In order to evaluate the potential deleterious effects induced by this ionizing radiation we studied, in lymphocytes from peripheral blood of those patients, the induction of chromosomal aberrations and micronuclei in different periods of time (1, 6 and 24 months) after iodine-131 therapy (2590 MBq). We observed that these parameters were slightly increased, in a persistent and significant way up to 24 months. No relevant changes in the parameters related to oxidative stress were found. Since whole body doses in thyroid cancer patients treated with iodine-131 are relatively low, we have evaluated the possible induction of an adaptive response, using the micronucleus test. Our results suggest the existence of a transient adaptive response, observed only one month after iodine-131 therapy, against the genotoxicity induced *in vitro* by mitomycin C. This work highlights the importance of the evaluation of genetic polymorphisms in the aetiology of papillary and follicular thyroid carcinoma and the need for a biological monitoring of the patients in order to better understand the effects induced by treatment with iodine-131.

Internal dosimetry (Operation and modelling of a Whole Body Counter and studies of biokinetic models)

A.D. Oliveira, M. Neves, M. Goulart, E. Fernandes, P. Nogueira, P. Teles, P. Vaz

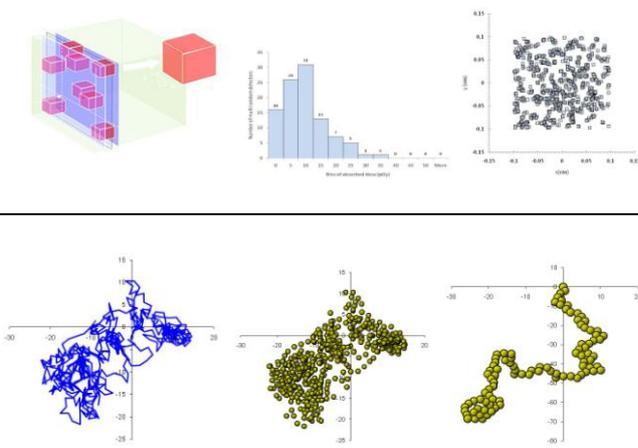
The internal dosimetry activities at the UPSR focused mainly on two topics: activities related to the operation of the Whole Body Counter, and activities related to the participation in several international projects related to the development of new radiotherapy agents. The Whole Body Counter (WBC), an Accuscan II from Canberra uses a vertical scanning system with a Ge detector. Data is analysed with the help of the Abacos 2k and Genie 2k spectroscopy software from Canberra. This enables identification, as well as activity quantification of the radionuclides present at the time of measurement, thus permitting radionuclide intake estimations. New students and researchers reinitiated this activity. These new activities include instrumental calibration and operation of the WBC, as well as a MC computational modeling of this system. Computational as well as instrumental calibrations are in good agreement. Further development is underway. This includes the beginning of international cooperations in order to perform quality assessments and expand internal expertise. Finally, biokinetic models for iodine contamination were developed accounting for body and organ contents as a function of time following intake, these were used to assess committed dose obtained from the radionuclide activities results of the WBC, and resulted in several oral presentations.

Internal dosimetry activities also involved the participation in projects related to the development of new radiotherapy agents with low electrons emitters, including internal dosimetry and biokinetics models. In collaboration with INETI and the Institute of Nuclear Chemistry and Technology (IcHTJ) of Warsaw, Poland under a EU Marie Curie Transfer of Knowledge project and Portugal/Poland scientific agreement.

Cellular and fundamental radiation dosimetry

A.D. Oliveira

This activity was developed in two main components: a) Concerning low dose of radiation and their radiobiological effects it was developed a new computational scoring algorithm ("Multi Random Detector") for Monte Carlo simulation allowing multidimensional analysis of the energy deposited in matter in order to correlate with cellular effects. This ongoing work resulted in an oral presentation at the LOWRAD 2008 conference; b) Geometry is a major issue in radiation dosimetry, perhaps still more important for biological cell clusters. In that sense, applications of the well known random walk and self-avoiding random walk numerical algorithms are under development for spheroids growth geometric models for cellular dosimetry.



Low Dose Non Target Effects: Genomic Instability, Bystander Effects and Adaptive Response

A.C. Antunes, M. Goulart, M.B. Martins

The radiobiology of low doses of ionizing radiation is currently a priority in scientific research of the biological effects of radiation. In recent years, new mechanisms of cellular response to ionising radiation have been unveiled, revealing non DNA-target effects which become more important in the low dose interval. These include trans-generational genetic instability, bystander effects in cells not directly hit by radiation and adaptive response of cells previously exposed to a conditioning dose. The Radiobiology Research Group of the GDR has developed a project to study the non-target effects of low doses of ionizing radiation. The study includes a research collaboration with the Hospital of Santarém, Radiology service, to study the long term genetic instability of human immortalized cells exposed to low doses of gamma radiation (CT radio-diagnostic doses) in the using cytogenetic biomarkers as endpoints. Bystander effects were also studied using human cell lines and different experimental approaches, including co-culture and medium transfer techniques. Other components of the project included the investigation of the adaptive response in bystander cells, exposed to signals from directly exposed cells. Our experiments showed that bystander cells have an average decrease of viability of 46% when compared to control non-irradiated cells, and that after a challenge dose of 1 Gy, bystander cells registered an increase of viability. This work was presented in an International Meeting on Radiobiology (Lowrad 2008).

Novel Radioprotectors and Radiosensitizers Originating from Natural Extracts or Organic Synthesis from Carbohydrate PrecursorsD. Ruivo, A. P. Rauter¹, J. Justino², M. Goulart

The use of carbohydrates as organochemistry precursors for the development of bioactive molecules is a thriving research area with strong potential for several fields, including energy production, nutrition, cosmetics, polymers, and also the medical field. The possible application of low dose selective apoptosis inducers to cancer therapy, or the use of radioprotectors in patient or worker radiation protection plans is an exciting area of Radiobiology research. Collaborative work has been started up with the Faculdade de Ciências, Grupo de Química dos Glúcidos, for the screening of cellular toxicity and modulation of low dose radiation effects of novel bioactive carbohydrate molecules, namely pseudo-c-nucleosides. Natural products are an alternative to synthetic drugs in many pharmacology applications, frequently with considerable advantages, including lower incidence of side effects. The research project on Radioprotectors and Radiosensitizers included the evaluation of extracts of Portuguese representative plant extracts, obtained by collaboration with the Escola Superior Agrária de Santarém. Several extracts of the plant *Salvia sclareoides*, some of them previously shown to be active antioxidants, were studied in human leukemia cells (K562). Cellular viability was assessed after low dose irradiation and short term exposure to the drug. The butanol and methanol extracts of *Salvia sclareoides* displayed the most striking effect regarding cell proliferation and radioprotective activity. K562 cells exposed to the mentioned extracts had a significant 2-fold increase in their viability in both the simple extract exposure and the combined extract/irradiation.

Salvia sclareoides ethanol extracts showed a lower but also significant radioprotective activity. In this research, we also showed a significant tumor cell death in samples exposed to the water salvia extract, which may provide new hope for leukemia patients. Further developments of this line of activity, will include detailed apoptosis studies. This work was presented in an International Meeting on Radiobiology (Lowrad 2008).

¹FCUL-CQB-GQG;²IPS-ESAS.**Participation of ITN in the n-TOF-Ph2 experiment at CERN (2nd year)**P. Vaz, I.F. Gonçalves, C. Cruz, J. Neves, C. Carrapiço, R. Sarmento, L. Ferreira¹, L. Távora²

An experimental programme is being carried out since 2001 by the n-TOF Collaboration (a consortium of 40 laboratories in Europe, U.S.A. and Japan) at the neutron time of flight (TOF) facility at CERN, using the CERN/PS accelerator complex. A single proton pulse of $7 \cdot 10^{12}$ protons of 20 GeV impinges on a lead target every 2.4 seconds. After collimation, a neutron flux of the order of 10^5 neutrons/cm²/pulse is available for cross section measurements in the detectors station located 185 m downstream the target area.

These cross-sections measurements are required in many applications such as the design of innovative Accelerator Driven Systems (ADS) for incineration of nuclear waste and energy production, radioisotope production for medical and industrial applications and many other subjects in Astrophysics, Nuclear Physics and Nuclear Technology. New or improved measurements of neutron cross-sections will also be very valuable for Radiation Shielding, Dosimetry and Monte Carlo Radiation Transport calculations. During 2008, ITN team members in cooperation with researchers from CEA/Saclay and INFN/Bari performed:

- the analysis of the ²³³U neutron capture data sets
- the analysis of the ²³⁶U neutron induced fission data sets
- Monte Carlo simulations of the neutron resolution function for the TOF spectrometer

The ITN participation was undertaken in the framework of a project funded by the Portuguese Foundation for the Science and Technology (FCT), entitled “Participation of ITN in the n_TOF-Ph2 experiment at CERN (Second Year)” (project ref. POCI/FP/81931/2007).

¹ DF/ IST;² C. de Instrumentação / U. Coimbra

EUROpean Research Programme for the TRANSmutation of High Level Nuclear Waste in an Accelerator Driven System (IP-EUROTRANS)

P. Vaz, I.F. Gonçalves, I. Paiva, R. Pires¹, Y. Romanets, P. Teles, R. Trindade

IP EUROTRANS is a European Union co-financed project (ref. FI6W-CT-2004-516520) in the 6th Framework Program EURATOM. The objective of IP EUROTRANS is the design and the feasibility assessment of an industrial ADS (Accelerator Driven System) prototype dedicated to the transmutation of high-radiotoxicity and long-lived radioactive waste. The Portuguese team, led by ITN, actively participated in:

- Dosimetry (dose and neutron flux distributions) and radiation shielding calculations,
- Assessment of the radiation damage of the structural components,
- Neutronics studies and assessment of reactivity variations with the insertion of control rods
- Reliability of the accelerator system, in the following domains:
- DM1-DESIGN – “*Development of a detailed design of XT-ADS and a conceptual design of the European Facility for Industrial Transmutation EFIT with heavy liquid metal cooling*” – participating in WP 1.2 (“Development and Assessment of XT-ADS and EFIT Designs”) and WP 1.3 (“High Power Proton Accelerator Development”).
- DM2 – ECATS – “*Experiment on the Coupling of an Accelerator, a spallation Target and a Sub-critical blanket*”, participating in WP 2.1 (Experiments at YALINA – current to flux reactivity on-line monitoring techniques, interim calibration techniques used at beam trips and full calibration techniques for kinetic parameters) and WP2.3 (The GUINEVERE project – Study of the reactivity monitoring methodology for an ADS in a modified lead VENUS reactor coupled to a modified continuous-beam GENEPI accelerator).

A report (deliverable) on the radiation damage of the XT-ADS was prepared under the coordination of the ITN team.

¹Fac. de Engenharia / Univ. Católica Portuguesa

EURISOL DS - Design Study of an European Isotope Separation On-Line Radioactive Ion Beam Facility
(Radiation Protection and Safety, Dosimetry and Shielding)

P. Vaz, J.G. Correia, I.F. Gonçalves, R. Luís, Y. Romanets

The Project EURISOL-DS is a Collaboration of twenty institutions and laboratories in European countries and CERN. Its activities are funded by the European Union in the 6th Framework Programme for Research and Development (“Research Infrastructures Action”).

EURISOL DS aims at performing the detailed design studies for the deployment in Europe of a world class Radioactive Ion Beam Facility, able to produce radioactive beams with much higher intensities than the ones currently available in other facilities worldwide. Very selective extraction methods combined to the high intensity of the beams will allow the discovery and study of new isotopes as well as the production of isotopes for a wide range of applications ranging from Fundamental Nuclear Physics and Astrophysics studies to Life Sciences, in particular Medicine. The innovative characteristics of such a facility are also associated to its multi-MegaWatt target unit where a high-intensity beam of protons of energy in the 1-2 GeV range will impinge on a high-Z material, mercury, tungsten or tantalum being currently considered as potential candidates. ITN is participating in the computational activities of the following sub-groups:

- WP2 (“Multi-MW Target Station”)
- WP5 (“Safety and Radioprotection”)

During 2008, the ITN team has performed, together with the CERN team, Monte Carlo simulation studies of the neutronics and dosimetry characterization and the shielding assessment of the so-called “MAFF-like” Target Unit of the installation.

The ITN participation was undertaken in the framework of one project funded by the Portuguese Foundation for the Science and Technology (FCT) and entitled “*Cooperation with CERN in the framework of the Portuguese participation in the project "EURISOL Design Study"*” (project ref. POCI/FP/81951/2007).

PATEROS - Partitioning and Transmutation European Roadmap for Sustainable Nuclear Energy

P. Vaz

PATEROS is a European Union co-financed Coordinated Action (ref. FP6-036418) in the 6th Framework Program EURATOM, under the specific programme for Research and Training in Nuclear Energy.

A closed fuel cycle is a prerequisite for making nuclear energy a sustainable one. This can be reached by deploying advanced partitioning and efficient transmutation systems to reduce the burden on the geological storage. This objective is of relevance both for countries committed to nuclear energy in the future and for countries not committed to a further deployment of nuclear energy. The objectives of this Coordinated Action is to deliver a European vision for the deployment of the partitioning and transmutation technology up to the scale level of pilot plants for all its components. During 2008, ITN has contributed to the preparation of reports in the framework of the Work Package 6 entitled “Integration and Evaluation of Resources and Time Planning.

CANDIDE – Coordination Action on Nuclear Data for Industrial Developments in Europe

P. Vaz, I.F. Gonçalves

CANDIDE is a European Union co-financed Coordination Action (ref. FP6-036397) in the 6th Framework Program EURATOM. It addresses the following two objectives:

1. Establishment of better links between academia, research centers and industry end users of nuclear data.
2. Assessment of nuclear data needs for advanced nuclear reactors. The emphasis is on the radioactive waste issue, i.e., either waste transmutation in critical or sub-critical devices or minimizing the production of nuclear waste in future nuclear reactors, as envisaged in, e.g., the GEN-IV systems.

The ITN team has participated during 2008 in the Work Package 3 entitled “Nuclear Data Assessment”, performing activities related to the assessment of the state-of-the-art nuclear data libraries.

SERVICES**1-Individual Monitoring Service: individual and environmental monitoring**

M. Martins, M. Pereira, M. Saraiva, S. Rangel, V. Batel, A. Calado, L. Freire, J.G. Alves

The Individual Monitoring Service (IMS) for external exposure at ITN is based on a TLD system that consists of two 6600 Harshaw readers and on the Harshaw 8814 TL card and holder containing two LiF:Mg,Ti (TLD-100) elements for the evaluation of $H_p(10)$ and $H_p(0.07)$. In 2008, the service monitored around 3,200 workers on a monthly basis raising approximately € 140.000,00. In order to establish and implement a monitoring method for extremity monitoring, two LiF dosimeter varieties (LiF:Mg,Ti TLD-100 and LiF:Mg,Cu,P TLD-100H) were further tested. Environmental monitoring is also performed for the National Radiological Environmental Monitoring programme. The aim of this work is to perform quarterly measurements of the ambient dose equivalent $H^*(10)$ in nine sites at nationally spread locations and in four sites at ITN *campus* with increased monitoring frequency. Nearly 1,400 dosimeters are annually allocated to this project. In 2008 the IMS took part in two intercomparison exercises, specifically, for whole body dose measurements organized by EURADOS (European Radiation Dosimetry Group), and for environmental measurements organized by CSN – Consejo de Seguridad Nuclear, the Spanish Nuclear Safety Council. Education and training related activities allowed the presentation of a MSc thesis (L. Freire) in 2008 and the on-going preparation of three more MSc thesis (M. Pereira, A. Calado and V. Batel).

2-Central Dose Registry: Collection and Analysis of Occupational Dose data

M.B. Martins, J.G. Alves

ITN is entrusted the task to create and maintain a Central Dose Registry (CDR) for occupational exposure, according to Decree-Laws 165 and 167 of July 2002 and more to Decree-Law 222 of November 2008. Presently the CDR contains the occupational exposure data of 42,119 workers monitored in Portugal in the period 1957-2007, representing the evaluation of 276,060 annual cumulative doses $H_p(10)$. The data stored at the CDR consists on the external dose evaluations in terms of the operational quantities $H_p(10)$ and $H_p(0.07)$ and on information concerning the worker's affiliation and type of activity. Data transfer between the CDR, the six monitoring services and companies operating in Portugal was performed on a quarterly basis (Decree-Law 222 (art. 12º e)). The database structure of the CDR is being improved so that data transfer can take place in a more effective way.

The analysis of the occupational dose data stored at the CDR is also an aim of this project, particularly in the case of high dose activities. The annual whole-body doses evaluated in the period 2000–2007 were analyzed and used to derive the distribution of workers by dose intervals for every profession and field of activity. Special attention was given to staff doses in interventional procedures, in the medical sector. The annual average doses and annual collective doses, as well as, the total average and total collective doses were also determined.

3-Safety Assessment

A.D. Oliveira, L. Freire, T. Antunes, D. Alves, P. Vaz

A master thesis is under development and two new ones are programmed in 2009. Radiation safety assessments of complex radiological facilities mainly in radiotherapy had been carried out together with the group RRW (Radioprotection and Radioactive Waste). These services are provided accordingly with international recommendations NCRP, IAEA, DIN, etc., resulting in several technical reports. One of the main problems encountered during this period was the implementation of the safety culture in several radiological facilities, which still remains a serious problem. Concerning radiation protection regulations some activity was accomplished from the point of view of qualified expert advisory in order to help the national authorities to fulfil the recommendations of IAEA and the European Community. Participation in IAEA committee RASSC it was a major goal of the activity mainly concerned with the implementation of the IAEA safety standards¹.

¹ "A Portuguese perspective of the role, duties and responsibilities for RPE, RPO, RW on ionizing radiation", C. Oliveira, R. Trindade, A. Oliveira et al., EUTERP 2008 meeting.