

Use of computer codes for radiation dosimetry calculations and shielding design

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Objectives

This activity aimed at applying computer codes for simulating and solving radiation protection dosimetry problems. We used state-of-the-art Monte Carlo computer codes such as MCNPX and a home made Monte Carlo code with several versions, MC-PHOTON, MCENTROPY and MCISOPHANTOM, which were tested with reasonable good results.

Nowadays computer codes are used in a wide variety of applications in all areas of radiation protection. We used both analytical and Monte Carlo computer codes in several fields:

- Radiation dosimetry.
- Shielding design.
- Cellular dosimetry.

Results

In radiation dosimetry:

Application of MCISOPHANTOM to one of the problem in the international intercomparison in the usage of computer codes (QUADOS).

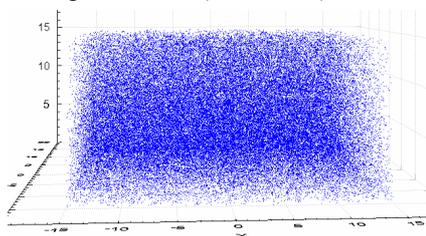


Fig. 1. Points of energy deposited in a water phantom from a parallel broad beam of 150 keV.

In radiation shielding:

We applied MCNPX to a dose assessment in a 650 keV electron irradiator for industrial applications, corresponding to a Portuguese industrial facility with higher technical international standards.

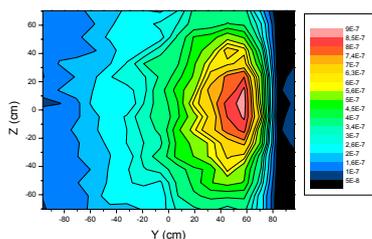


Fig. 2. Photon flux distribution inside the accelerator chamber, per incident electron (along the Y-axis) in the transverse plane containing the electron beam

In cellular dosimetry:

Cellular dosimetry is a special branch of radiation dosimetry, at the confluence of several fields such as radiation physics, biology and chemistry.

We studied several dosimetric approaches mainly analytical procedures but we intended to extend the calculations to Monte Carlo approaches.

These calculations have a very strong dependence from the geometric properties of cells which are very complex to simulate and is one of the challenges in this field.

We participated in interdisciplinary projects jointly with other groups of ITN.

Published, accepted or in press work

1. A.D. Oliveira. Esboço de um programa de protecção radiológica: do trabalhador à autoridade reguladora, *Radioprotecção*, **2**, 4-5, Dec. 2003 and May 2004.
2. A.D. Oliveira, C. Oliveira, Comparison of deterministic and Monte Carlo methods in shielding design, *Radiat. Prot. Dosim.* (accepted).
3. A.D. Oliveira, Photon track evolution, *Radiat. Prot. Dosim.* (accepted).
4. A.D. Oliveira, Analysis of the photon track structure for low energy photons, *11st Int. Congress of International Radiation Protection Association*, Madrid, Spain 2004.
5. A.D. Oliveira, Air kerma backscatter factor determined by Monte Carlo using extrapolation procedures from energy deposited data, *Proc. Intercomparison on the usage of computational codes in radiation dosimetry*, ENEA – Italian National Agency for New Technologies, Energy and the Environment, Bologna, Italy 2004.
6. M. Neves, A. Kling and A. D. Oliveira. Potential Radionuclides for Targeted Radiotherapy. *10th Int. Conf. on Radiation Shielding (ICRS-10) and 13th Biennial Topical Meeting of the Radiation Protection and Shielding Division of the American Nuclear Society (RPS2004)*. Madeira, Portugal, 2004.

Radiobiology and Dosimetry by Cytogenetic Methods Applied to Populations Living near Old Uranium Mining Areas

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Objectives

Evaluation of the biological effects of low-level ionizing radiation and genotoxic damage as a result of chronic exposure to ionizing radiation in populations living near old uranium mines and tailings.

This project – called «MinUrar» (“Minas de urânio e seus resíduos: efeitos na saúde da população”) – is led by the Instituto Nacional de Saúde Dr. Ricardo Jorge (INSA). Other participating institutes are ITN – DPRSN, IGM, Centro Regional de Saúde Pública do Centro, Ministério da Saúde – Administração Regional de Saúde da Zona Centro, Hospital de S. Teotónio, SA – Viseu. The project aims at investigating the health effects in the populations living near uranium mines due to exposure to radon and other radioactive elements.

Methods

The possible incidence of diseases or other health problems, resulting from exposure to genotoxic contaminants, is determined through the search of chromosomal translocations in lymphocytes from peripheral blood cells. Also the cytogenetic research includes analysis of blood cells irradiated with 2 Gy gamma radiation for the challenge assay. This is done by the FISH technique (Fluorescent *In Situ* Hybridization) and image analysis. Blood samples are analysed in the DPRSN and INSA.

Results

Cell cultures from the first blood samples that have failed were recollected this year, and stored in the laboratory. The blood samples were processed for analysis by the FISH technique.

Also the optimisation and selection of the probe used for the FISH technique was somewhat difficult. This probe is marked specifically for chromosomes 1, 2, and 4.

For each sample DPRSN and INSA will evaluate 2000 metaphases in the non-irradiated samples and 700 metaphases in the irradiated ones.

Until now our group have already studied 30325 metaphases for non-irradiated samples and 9746 for the irradiated one. The number of complete cases studied is 25.

Final results of this epidemiological study shall be achieved in 2005.

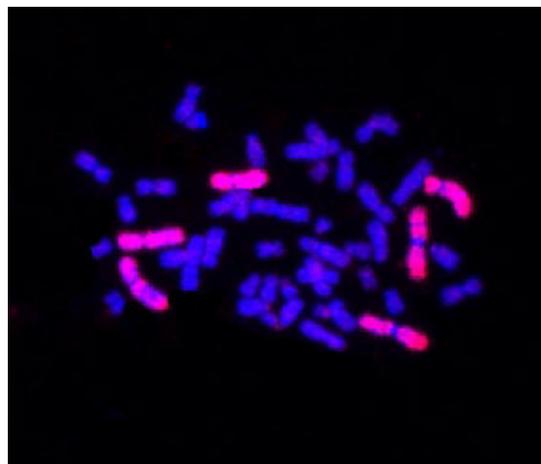


Fig. 1. Normal metaphase obtained by whole chromosome painting for chromosomes 1, 2 and 4; non irradiated sample.

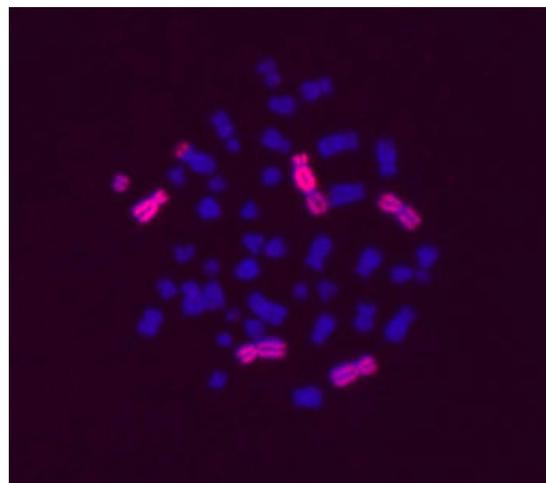


Fig. 2. Metaphase from an irradiated sample (2 Gy) with a dicentric (a), a translocation (b) and an acentric fragment (c).

Published, accepted or in press work

1. “Minas de Urânio e seus Resíduos. Efeitos na Saúde da População”. *MINURAR progress report*. Setembro de 2004.

Synthesis and characterization of ^{153}Sm -indazolbispfosphonates

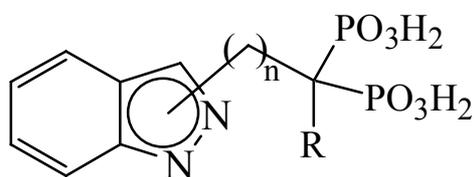
M. A. Neves, F. Teixeira¹, I. Antunes¹

Objectives

The aim of this work is the production of radiolanthanides at the Portuguese Nuclear Reactor, and to collaborate with other national institutions. The synthesis, characterization and *in vitro* evaluation of indazolbispfosphonates with Sm-153 for radionuclide therapy

Results

Novel indazole BPs (bispfosphonates) substituted at different C- or N- positions of indazol were complexed with ^{153}Sm and characterized by radiochemical techniques.



R=H, OH

HAP (hydroxyapatite) binding simulating bone adsorption of complexes with indazol substituted in C3 and N1 have shown from 0-20 mg of HAP higher % binding for N1 substituted BPs, while for 20-80 similar result was obtained (Fig. 1). This could be explained by a distinct interaction between complexes and HAP. Studies on molecular modeling could confirm this hypothesis.

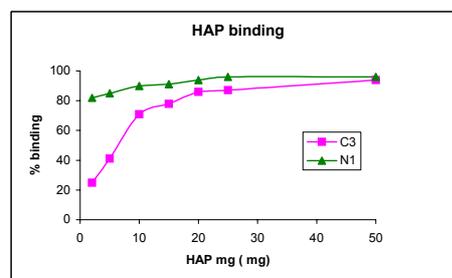


Fig. 1. HAP % binding of indazolBPs

Published, accepted or in press work

1. F. Teixeira, I. Pereira, M. Curto and M. Neves. Synthesis and characterization of new indazolbispfosphonates. *Proc. 16th Int. Conf. on Phosphorus Chemistry-ICPC*, Birmingham, UK, 4-9 July 2004.
2. F. Teixeira, Inês Pereira, M. João M. Curto e M. Anjos Neves. Novos Indazolbispfosfonates para o Metabolismo Mineral do Osso, *XIX Encontro Nac. da Sociedade Portuguesa de Química*, Coimbra, 15-17 April, 2004.

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Participation of ITN in the n-TOF experiment (PS213) at CERN (Second and Third Year)

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Objectives

The n-TOF Collaboration, a consortium of 40 laboratories in Europe and U.S.A., has proposed an ambitious programme to perform high accuracy measurements of neutron cross-sections in the range from 1 eV to 250 MeV. An experimental programme (PS213) is being carried out since 2001 at the neutron time of flight (TOF) facility at CERN, using the CERN/PS accelerator complex in order to measure neutron cross sections that are required in many emerging applications, such as Accelerator Driven Systems (ADS), and that require the use of high-intensity and medium-energy (in the hundreds of MeV) proton beams impinging on a thick target of a heavy element. New or improved measurements of neutron cross-sections will also be very valuable for Radiation Shielding, Dosimetry and Monte Carlo Radiation Transport calculations.

Results

During 2004, ITN researchers participated in the data taking shifts at CERN, developed and tested prototypes for the voltage divider circuit attached to the photomultipliers equipping the the Barium Fluoride (BaF_2) calorimeter modules and participated in the data analysis for of the neutron capture cross-sections and determination of the resonance parameters of the nuclide ^{94}Zr . During this period files for the simulation of the detection efficiency to photons and to neutrons of the newly built BaF_2 calorimeter modules, namely those containing the geometric description of the detector modules were prepared.

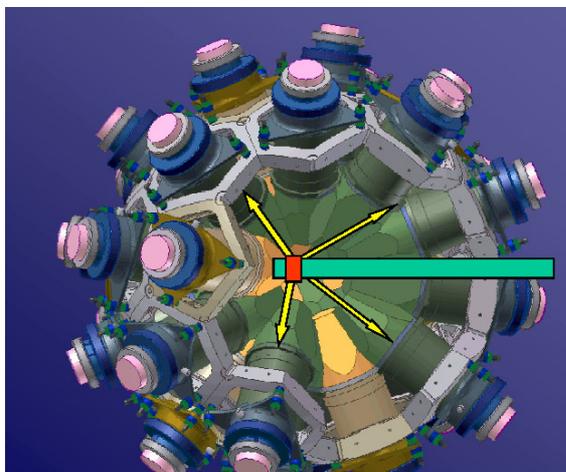


Fig.1. The n-TOF Barium Fluoride calorimeter.

It is a 50 cm diameter sphere made of 40 BaF_2 modules of prismatic pentagonal and hexagonal

geometry, each equipped with a photomultiplier and a voltage divider and mounted on a aluminium honeycomb structure. In the picture, the beam pipe and sample are schematically shown. The construction of the calorimeter is of the responsibility of a consortium of organizations led by FZK (Germany). ITN participates in the development of the voltage divider circuits attached to the photomultipliers.

Published, accepted or in press work

1. U. Abbondanno *et. al.* (The n_TOF Collaboration), New Experimental validation of the Pulse Height Weighting Technique for Capture cross-section measurements, *Nucl. Inst. & Meth. A* **521**, 2-3 (2004) 454-467.
2. J. Pancin *et. al.* (The n_TOF Collaboration); Measurement of the n_TOF beam profile with a micromegas detector, *Nucl. Inst. & Meth. A* – **524**, 1-3 (2004) 102-114.
3. U. Abbondanno *et. al.* (The n_TOF Collaboration), Neutron Capture Cross Section Measurement of ^{151}Sm at the CERN Neutron Time of Flight Facility (n_TOF), *Phys. Rev. Lett.* **93** (2004) 161103.
4. G. Lorusso *et. al.* (The n_TOF Collaboration), Time-energy relation of the N_TOF neutron beam: energy standards revisited, *Nucl. Inst. & Meth. A* -**532**, 3 (2004).
5. U. Abbondanno *et.al.* (The n_TOF Collaboration) The data acquisition system of the neutron time of flight facility n_TOF at CERN, *Nucl. Inst. & Meth. A* (in press).
6. G. Tagliente *et. al.* (The n_TOF Collaboration), Measurement of the $^{90,91,92,94,96}\text{Zr}(n,g)$ at n_TOF, *Nucl. Phys. A* (in press).
7. U. Abbondanno *et. al.* (The n_TOF Collaboration), Measurement of the $\text{Sm-151}(n,g)$ cross section at n_TOF, *Nucl. Phys. A* (in press).
8. U. Abbondanno *et. al.* (The n_TOF Collaboration), Neutron capture cross section measurements for nuclear astrophysics at CERN n_TOF, *Nucl. Phys. A* (in press).

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²Centro de Instrumentação - Universidade de Coimbra.

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Preliminary Design Studies of an eXperimental Accelerator Driven System (PDS-XADS) (EU contract N^o FIKW-CT-2001-00179)

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Objectives

The European Commission's Green Paper entitled "Towards a European Strategy for the Security of Energy Supply" clearly pointed out the importance of nuclear energy in Europe. It also points out that the nuclear industry has mastery of the entire nuclear fuel cycle with the exception of waste management and for this reason, "focusing on waste management has to be continued".

Most of the hazard from the *spent fuel* from nuclear power plants stems from only a few chemical elements – plutonium, neptunium, americium, curium and some *long-lived fission products* (LLFP) such as iodine and technetium at concentration levels of grams per ton. These radioactive by-products, although present at relatively low concentrations in the spent fuel, are a hazard to life forms when released into the environment. As such, their disposal requires isolation from the biosphere in stable deep geological formations for long periods of time.

Accelerator Driven Systems (ADS) consist of a high-intensity proton accelerator of energies in the range 600-800 MeV impinging a target of a heavy element. The spallation reactions in the target material generate a very high neutron flux that feeds a surrounding sub-critical core system. The very high-flux of neutrons is required to sustain the *transmutation* processes by which the minor actinides and long-lived fission products can be "transformed" in nuclide species with a shorter lifetime, typically of hundreds of years (instead of dozens of thousands of years), and smaller radiotoxicity. Accelerator Driven Systems would have a great potential for nuclear waste transmutation and could be used to reduce the burden to underground repositories.

Results

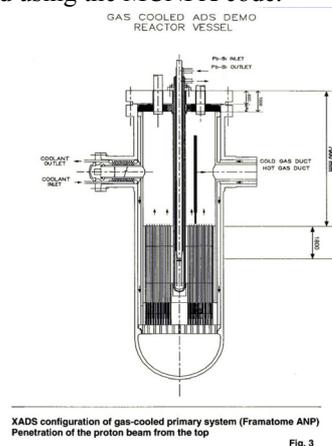
The studies were organized around Work Packages (WP). The ITN team is directly involved, in the computational activities of:

WP 4.3 – Target Unit design – Spallation and neutronic calculations of the target unit (heat distributions, evaluation of the spallation and activation products, their energy and volume distributions). Work in cooperation with Framatome-ANP (WP leader), Ansaldo Nucleare (Italy), ENEA (Italy), FZK (Germany), SCK-CEN (Belgium), UPM (Spain), KTH (Sweden) and UMM (Poland).

WP 3 – Accelerator studies – Requirements for the operation of the XADS Accelerator (6 mA nominal proton beam current and 600 MeV energy) and the technical answers on issues such as stability,

accidental situations and potential for other applications. Work in cooperation with FE-UCP (Faculdade de Engenharia da Universidade Católica Portuguesa), CEA, CNRS and IN2P3 (France), INFN (Italy), IBA (Belgium), Univ. Frankfurt (Germany).

The following picture shows one of the possible configurations for the XADS in which the ITN team is involved. It consists of a gas-cooled Lead-Bismuth Eutectic target with a window separating the accelerator and the target. Studies and Monte Carlo simulations concerning this design were performed using the MCNPX code.



Published, accepted or in press work

1. D. Coors et. al, Target Units for XADS primary systems, Conf. EURADWASTE 04, Luxemburg, March 2004.
2. Requirements for the XADS Accelerator and The Technical Answers, *Deliverable D9*.
3. Definition of the XADS Class Reference Accelerator Concept and needed R&D, *Deliverable D63*.
4. Spallation and Neutronic Calculations Generating the Heavy Particles and Spallation Products Volumetric Distribution and Energy Spectrum, *Deliverable D60.1*.
5. Target Unit - Summary Report, *Deliverable D74*.
6. Study on the Radiation Damage in the Target Window of the PDS-XADS Gas Cooled Reactor Core, *DOC/04/349*.

¹FE-UCP – Faculdade de Engenharia, Universidade Católica Portuguesa

Study of polymorphisms in a population of thyroid cancer patients

Octávia Monteiro Gil

Objectives

This work aims at investigating different polymorphic genes of non familial thyroid cancer patients, to see if they are involved in the susceptibility to this type of cancer.

For this purpose, we conducted a hospital-based case control study in a Caucasian Portuguese population to evaluate the potential modifying role of glutathione S-transferase polymorphism (*GSTM1*, *GSTT1*, and *GSTP1* genotypes) in thyroid cancer occurrence. We have also begun the study of the association of *ERCC2* with non-familial thyroid cancer risk.

Methods

This study of polymorphism was determined by polymerase chain reaction (PCR) and restriction fragment length polymorphism (RFLP).

The work was performed in the Department of Genetics of New University of Lisbon, under the supervision of Prof. J. Rueff.

Results

The results obtained in this study for thyroid cancer show that the combined genotype *GSTM1**0, *GSTT1**0, and *GSTP1* Ile/Ile results in a significant risk increase for thyroid cancer, particularly for papillary tumors, suggesting that alteration of ability of detoxification by GST enzyme family could lead to an increase risk for this tumors.

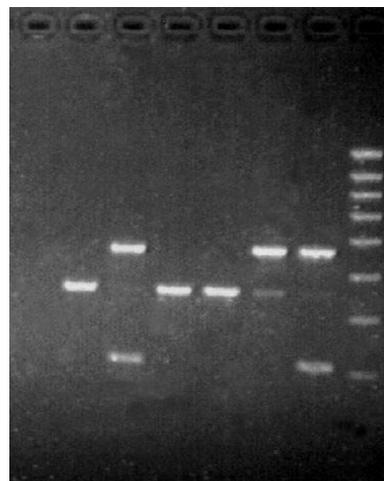


Fig.1. Gel-electrophoresis depicting *GSTM1* and *GSTT1* polymorphism from thyroid cancer patients.

Published, accepted or in press papers

1. J. Gaspar , S. Rodrigues, O. Monteiro Gil, I. Manita, T. C. Ferreira, E. Limbert, L. Gonçalves, J. Esperança Pina and J. Rueff Combined effects of glutathione S-transferase *GSTM1*, *GSTT1* and *GSTP1* polymorphisms and thyroid cancer risk, *Cancer Genetics and Cytogenetics*, **151** (2004) 60-67.
2. A. S. Rodrigues, N. G. Oliveira, O. Monteiro Gil, A. Léonard and J. Rueff, Use of cytogenetic indicators in radiobiology, *Radiation Protection Dosimetry*, (accepted).
3. J. Rueff, A.S. Rodrigues, N G. Oliveira, O. Monteiro Gil, Cytogenetic biomarkers in radiobiology. *10th Int. Conf. on Radiation Shielding (ICRS-10) and 13th Biennial Topical Meeting of the Radiation Protection and Shielding Division of the American Nuclear Society (RPS2004)*. Madeira, Portugal, 2004.

Radiological Safety Assessment

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Objectives

The main activity in this field is to make reports in radiological safety assessment. Most of the services are requested by the General Directorate of Health of the Ministry of Health. Those reports are used to support the licensing of all the radiological installations in the country from medicine to industry.

Results

The results of this activity are 443 annual reports some of which were short recommendations and others more complexes, which are listed as internal reports. We make a wide diversity of assessment reports in medical procedures such as diagnostic X-rays, radiation therapy and nuclear medicine. Some of the major radionuclides originating radiation exposures are I-131, Tc-99m, Co-60, Ir-192, Cs-137 and others. Industrial radiography uses both sealed sources and X-rays. Others industrial applications use portable gauges containing radioactive sealed sources. There are also some state-owned facilities and laboratories of university research.

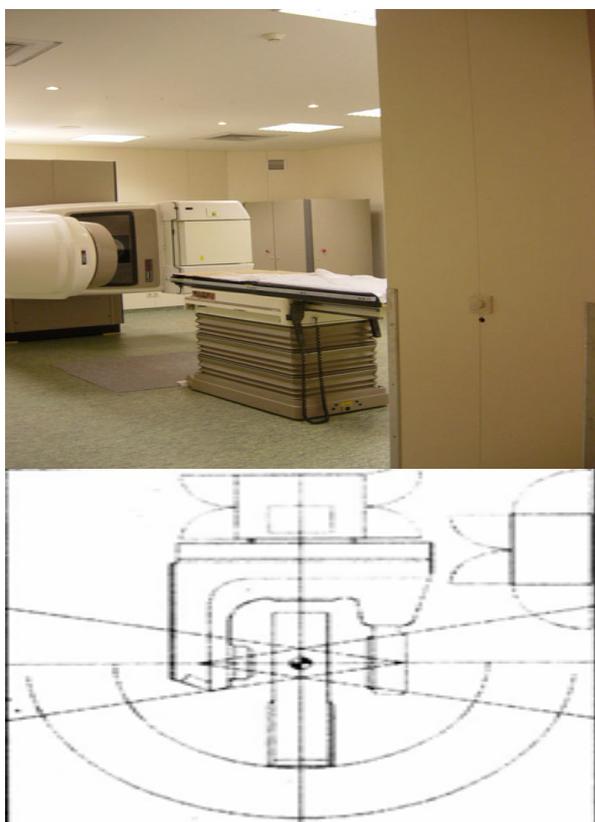


Fig. 1. Linear accelerators in medicine. These are radiological facilities with high radiological risk, whose assessment guarantees their safe use.

Published, accepted or in press work

1. M. Ângelo and A.D. Oliveira, Estudo de avaliação das condições de segurança radiológica da instalação de medicina nuclear do IPOFG – Porto, *Int. Rep.DPRSN – C n° 13/2004*.
2. A.D. Oliveira, Estudo de avaliação de segurança radiológica da instalação TAGUSLIP para utilização de fontes seladas e não seladas, *Int. Rep.DPRSN-C, n° 20/2004*.
3. A.D. Oliveira and M. Ângelo, Verificação das condições de segurança radiológica da instalação de imagiologia do Hospital Militar Principal, *Int. Rep.DPRSN-C, n° 23/2004*.
4. P.Vaz and A.D. Oliveira, Avaliação das condições de segurança radiológica da COFICAB Portugal – Companhia de fios e cabos, Lda, *Int. Rep.DPRSN-C, n° 30/2004*.
5. A.D. Oliveira and Luís Portugal, Avaliação das condições de segurança radiológica da CHIP – Centro de Higienezação por ionização de produtos, Lda, *Int. Rep.DPRSN-C, n° 35/2004*.
6. M. Ângelo and A.D. Oliveira, Avaliação das condições de segurança radiológica do serviço de medicina nuclear do Hospital Geral de S.^{to} António, *Int. Rep.DPRSN – C n° 36/2004*.
7. M. Ângelo and A.D. Oliveira, Estudo de avaliação das condições de segurança radiológica dos laboratórios do IBILI – F. M. da Universidade de Coimbra, *Int. Rep.DPRSN – C n° 63/2004*.
8. M. Ângelo and A.D. Oliveira, Avaliação das condições de segurança radiológica da instalação de braquiterapia do IPOFG – Coimbra, *Int. Rep.DPRSN – C n° 64/2004*.
9. M. Ângelo and A.D. Oliveira, Estudo de avaliação das condições de segurança radiológica da instalação de medicina nuclear da Diaton - Leiria, *Int. Rep.DPRSN – C n° 67/2004*.
10. M. Ângelo, Supervisor: A.D. Oliveira, Estudo de avaliação de segurança radiológica do serviço de medicina nuclear do Hospital Geral de S.^{to} António – Porto, *Int. Rep.DPRSN – C n° 68/2004*.
11. M. Ângelo, Supervisor: A.D. Oliveira, Estudo de avaliação de segurança radiológica do Laboratório de Investigação em Biologia Molecular – Universidade do Algarve, *Int. Rep.DPRSN – C n° 73/2004*.

