Radiological Risk and Safety Assessment

A. D. Oliveira

In 2006 IAEA published the "Fundamental Safety Principles", report N.º SF-1. This publication has provided a major opportunity to take a top-down approach for further developments of safety standards in order to improve their structure. The publication of this fundamental report provided also a great opportunity to change procedures that misapply the IAEA safety standards in the activities of ITN and also at national level. For a long time the General Directorate of Health (DGS) of the Ministry of Health, the entity with the legal competence to license facilities and activities, asked to ITN to assure some of the regulatory competences such as the technical validation of all the radiological facilities and activities in the country. However, at the same time the ITN also assumed some of the responsibility for safety of the owners of the radiation facilities. During the year 2006 we gave further steps forwards in order to implement the safety fundamental report SF-1, mainly the principles 1 and 2.

The first aim was to implement the principle 1, responsibility for safety: "The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risk".

The principle 3 of the report SF-1 is about leadership and management for safety: "Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks".

Concerning the principle 2, which is about the role of government, while research institute and radiation user, ITN should not belong to the regulatory body, hence we didn't make any actions.

As a service provider it was decided to concentrate in radiation safety assessments only for more complex facilities such as radiation therapy and nuclear medicine, in order to allow an increase in the research activities. Concerning scientific topics in radiation protection our scope are radiation dosimetry, biological effects of radiation and the relationship with risk estimation.

The research activity of the group included biologic effects of radiation, interventional radiology, radiation dosimetry with simulations and the application of the entropy concept and cellular dosimetry. Several projects were submitted to FCT.

A main concern is the application of techniques of chromosome painting with DNA fish probes which includes the cytogenetic analysis in blood samples of people exposed to radiation. This work needs urgent funds and human resources in order to avoid their disappearance. In that sense some projects were submitted to FCT.

Research Team

Researchers

A. D. OLIVEIRA, Aux Researcher, Group Leader
M. A. NEVES, Princ. Researcher
P. VAZ, Princ. Researcher
O. GIL, Aux. Researcher

Students

P. CARDOSO, grantee FCT
L. FERNANDES, grantee PEPAP

Technical Personnel

T. ANTUNES, superior technician

Collaborators

M. M. SARAIVA
D. ALVES

Radiological Safety Assessment

A.D. Oliveira, P. Vaz, T. Antunes, M. Saraiva

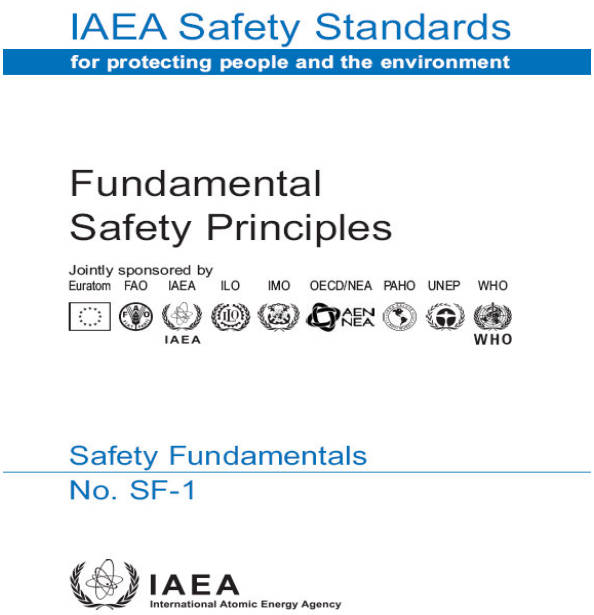
Objectives and activity

Application of the IAEA "Fundamental Safety Principles", report N.º SF-1.

In accord with principle 1, the ITN is responsible for the safety of its facilities and activities. It should not assume the responsibility for safety of others. It was in development the internal radiation protection program and this group was collaborated in that task.

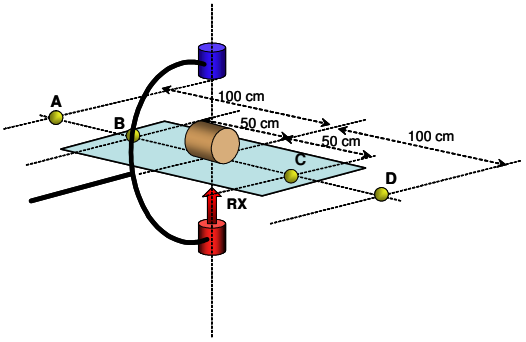
One of the changes introduced were to furnish to the General Directorate of Health (DGS) some basic recommendations for simple radiological facilities and activities, for example, some application of sealed sources in industry, or intra-oral facilities in dental radiology. For these facilities the DGS stopped the technical advisory request in a case-by-case base.
We focus the technical advisory in the general requirements and the trend is to stop the case by case assessment.

For the implementation of the principle 3, we elaborated a general basic radiation protection program that all of the owners of radiation protection facilities and activities should implement. This general radiation protection program was furnished to the DGS in order to be used in their authorizations activities.
The international trend is to add the radiation protection procedures to the general quality system.



Risk Evaluation in Interventional Radiology
A. D. Oliveira, L. Fernandes

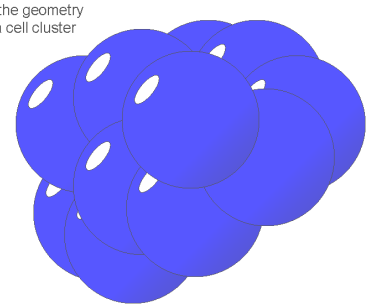
This project started in 2006 by the characterization of interventional radiology: facilities, activities and procedures. Plans were made for the physical and dosimetric characterization of the radiation field through several methodologies: theoretical, experimental and computational. Preparations were also taken for the field work and metrological verification of the equipment to be used.
It was submitted a project to FCT which involves 12 persons of the DPRSN and 4 persons of the "Hospital S.ta Maria" in Lisbon, aiming a full characterization of the risks of this activity. A master student is developing work within this project.



Cellular Dosimetry
A. D. Oliveira, M. A. Neves

The aim of this work is to develop an analytical algorithm suitable for computational implementation in cellular dosimetry based on the MIRD approach, allowing several degrees of freedom such as the number and position of cells, the number of cells contaminated and the modes of contamination. The user can apply the values of S-factor that he wants, allowing it to compare different values of S-factors and their importance for the cell cluster dose. The absorbed dose to a cell cluster is obtained from all the basic unit of dosimetry that exists in the cluster. Applications to several cell clusters will be tested

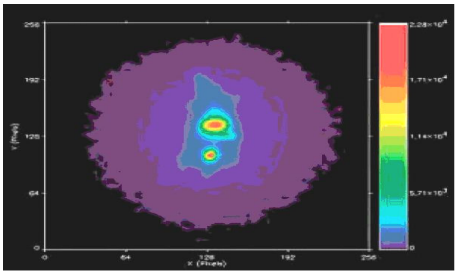
Example of the geometry involved in a cell cluster



Targeted radiotherapy
M. Neves

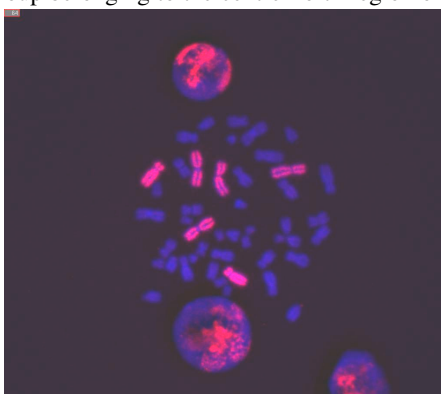
This project involves radionuclide production of Sm-153, Re-186 and Lu-177, to assist other projects. In collaboration with national institutions (INETI-Instituto Nacional de Engenharia e Tecnologia Industrial, Lisboa, Portugal and IBFBM - Instituto de Biofísica e Biomatemática, Faculdade de Medicina da Universidade de Coimbra.

- Novel hidroxi- and aminobisphosphonates: quelation, molecular modelling and biologic studies-INETI
- Lanthanide(III) Complexes of Glycoconjugates for Lectin-Mediated Medical Imaging-IBFBM.
- Assessment of Gd(III)-EPTPA, a new self-assembling Gd(III)-chelate: biodistribution and gamma imaging of the ^{153}Sm(III)-labeled ligand - IBFBM.
- Biodistribution and pharmacokinetics of variously molecular sized^{186}Re-polyethyleneiminomethylphosphonate complexes as potential selective therapeutic bone agents in the normal rats and in nude mice with xenotransplant of osteosarcoma model - IBFBM. Also in collaboration with University of Pretória and NECSA-Nuclear Energy Corporation of South Africa.



Radiobiology and dosimetry by cytogenetic methods applied to populations living near old uranium mining areas and compared with population living in areas without uranium mines
P.A. Cardoso Painço, O. Monteiro Gil

We proceeded with the work, started in partnership with INSA, into the 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 (Canas de Senhorim). The project, funded by the Ministry of Health (Resolução da Assembleia da República nº 34/2001) - call «MinUrar» ("Minas de urânio e seus resíduos: efeitos na saúde da população") aims at investigating the health effects in this population due to exposure to radon and other radioactive elements. Up to now we have already two groups completely studied, one from people living near the uranium mines, the other a control group belonging to the centre-north region of the country, but not living near uranium mines. The report with the results have already been sent for publication. A third populational group, belonging to a region from Alentejo (without uranium mines) was incorporated in this study to serve as reference population. For these populations, for each individual (a total of 30 individuals will be studied) we will study 2000 metaphases for the unirradiated samples and 700 for the samples of the same blood irradiated *in vitro* with 2 Gy gamma radiation for the challenge assay. This assay aims to determine the cell's competence for DNA damage repair. Equally in this study, chromosomes 1, 2, 4 were analysed for chromosomal translocations, by the FISH technique (Fluorescent *In Situ* Hybridization). For this group and until this moment in ITN we have already studied 25598 metaphases in unirradiated samples and 10401 in irradiated ones.



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

P. Vaz[1], I.F. Gonçalves[2], I. Paiva[1], R. Pires[3], Y. Romanets[4], R. Trindade[1]

IP EUROTRANS is a European Union co-financed project (ref. FI6W-CT-2004-516520) in the 6th Framework Program EURATOM. The work is focused on the transmutation of high-level waste from nuclear power plants using an Accelerator Driven System (ADS). Due to the fact that the strategy of partitioning and transmutation could reduce the radiotoxicity of high-level wastes dramatically and thus ease the discussion about the long-term safety assessment of a final repository, any step towards the technological realisation of transmutation in Europe will have a positive influence on the improvement of public acceptance of nuclear electricity production. The objective of IP EUROTRANS is the design and the feasibility assessment of an industrial ADS prototype dedicated to transmutation, together with the definition of a backup solution. The necessary R&D results in the areas of fuel, technology and nuclear data will be made available, together with the experimental demonstration of the ADS component coupling. The outcome of this work will allow to provide a reasonably reliable assessment of feasibility and an estimate of cost for an ADS based transmutation, and to decide on the detailed design of an ADS and its further construction, if there is a more general decision to go ahead with ADS-based transmutation. The Portuguese team, led by ITN, participates 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")
  - WP 1.3 ("High Power Proton Accelerator (HPPA) 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 during loading/start-up procedures)
  - WP2.3 (The GUINEVERE project – Study of reactivity monitoring methodology for an ADS in a modified lead VENUS reactor coupled to a modified continuous-beam GENEPI accelerator)

1 – ITN / DPRSN; 2 - ITN/ Physics Sector; 3 – Fac. de Engenharia / Univ. Católica Portuguesa; 4- project fellow

Participation of ITN in the n-TOF experiment (PS213) at CERN (fourth year)

P. Vaz[1], I.F. Gonçalves[2], C. Cruz[2], J. Neves[2], C. Carrapiço[3], C. Santos[3], L. Ferreira[4], L. Távora[5]

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. 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/cm^2/pulse is available for cross section measurements in the detectors station located 185 m downstream the target area.

These cross-section measurements are required in many emerging applications that require the use of high-intensity and medium-energy (in the hundreds of MeV) proton beams impinging on a thick target of an heavy element. These applications range from the design of innovative Accelerator Driven Systems (ADS) for incineration of nuclear waste and energy production, radioisotope production for medical and industrial applications and to 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 2006, ITN researchers in cooperation with researchers from CIEMAT/Madrid and CEA/Saclay:

- Participated in the checks of the time stability of the behaviour of the the TAC calorimeter and the Silicon monitors and assessed the quality of the data taken during 2004
- Participated in the design studies of the new shielding system for the TAC calorimeter, performing simulations using the state-of-the-art Monte Carlo program GEANT4
- Performed Monte Carlo simulation studies of the neutron and gamma fluxes for alternative targets at n-TOF, for different materials (e.g. Tungsten) and geometries, using the Monte Carlo program MCNPX
- Participated in the analysis of the ^{233}U data
- Contributed to the proposal for new measurements during n-TOF-Phase 2, to start during 2007, namely the measurements of the neutron capture cross-sections for iron and nickel isotopes.

1- ITN / DPRSN; 2 – IST / Physics Department; 3 – project fellow; 4- DF/ IST; 5 –C. de Instrumentação / U. Coimbra

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.

The World Energy Council's *WEC Statement 2000* points out that although global reliance on fossil fuels and large hydro will remain strong through 2020, these will not be able to meet the world's longterm electricity demand in a sustainable manner. 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. ITN contributes to the activities of:

- WP1: Rational and added value of P&T for waste management policies
- WP2: Review & selection of Relevant Fuel Cycle Strategies in Europe supplemented by Regional Context for Development and Deployment.
- WP6: Integration and Evaluation of Resources and Time Planning.

CONRAD – COordinated Network for RAdiation Dosimetry

P. Vaz, I.F. Gonçalves[1] , C. Carrapiço[2] – SG4/WP4/WP7

A.D. Oliveira[1], L.T. Fernandes[3] – SG2/WP7

The Project CONRAD is a collaborative effort led by the Technical University of Delft and involving several European institutions under the umbrella of EURADOS (the European Radiation Dosimetry group). Its activities are funded by the European Union in the 6th Framework Programme for Research and Development.

The ITN team participates in the determination of patient and staff doses in interventional radiology in collaboration with the "Hospital de Santa Maria" concerned with the following Work Packages of CONRAD:

- WP4 - Assessment of Uncertainties in Computational Dosimetry
- WP7 – Dosimetry for Radiation Protection of Medical Staff

In this context, it participates in the computation of two exercises entitled "Medical Staff Dosimetry in Interventional Cardiology" and in the measurement of staff doses, aiming at estimating the effective dose to the cardiologist due to the X-ray machine and to compare it with the personal dosemeter readings. The importance of wearing protective clothes (lead equivalent apron, thyroid collar, etc.) are used, as well as the influence of parameters such as the beam geometry and quality, the position of the dosemeter (above or below the apron) and the relevance of the usage of double dosimetry (one dosemeter above and another below the apron) will be performed. The ultimate goal is the determination of the effective dose to the professionals exposed.

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1 – ITN / Physics Sector; 2 – ITN Fellow

EURISOL DS - Design Study of an European Isotope Separation On-Line Radioactive Ion Beam Facility

P. Vaz, J.G.Correia[1], I.F. Gonçalves[1]

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 ("Target Design Studies")
- WP5 ("Radiation Protection Issues"

In the near future, it is foreseen the involvement in the project of other ITN teams and the utilization of several infrastructures available at the ITN campus in support of the project activities.

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1 – ITN / Physics Sector