

Radiological Protection and Safety Unit



Radiological Protection and Safety Unit

Pedro Vaz

The main activities of the Radiological Protection and Safety Unit (UPSR) were i) research and development ii) technical services iii) participation in intercomparison exercises involving nuclear and radioanalytical techniques iv) education and training and v) representation in national and international technical and scientific committees.

In the last quarter of 2008, a major effort was undertaken in order to start the preparation of the accreditation of the laboratories of the UPSR for several radioanalytical techniques in use. This effort is to be pursued during 2009.

The scarcity of human resources (researchers, technicians and research fellows) required to meet the increasingly higher volume of work resulting from the legal obligations and service providing duties as well as from the involvement in research and development projects, is presently seriously limiting and hampering the intervention capacity of the UPSR.

The succinct description of the activities is as follows:

Research and Development activities:

Special emphasis has been devoted to i) fostering and establishing partnerships between groups of UPSR researchers and experts in other sectors of ITN and in other Portuguese and foreign institutions and to ii) the participation of UPSR researchers in national and international consortia conducting R&D activities and projects funded by the European Union (ongoing in the E.U. 6th Framework Programme or submitted to the E.U. 7th Framework Programme), and by the Portuguese Foundation for Science and Technology (FCT), among others. Considering the trends in Radiation Protection and Radiation Dosimetry, as well as the UPSR mission and competences, special efforts were undertaken to strengthen the involvement of UPSR and its researchers in areas such as Computational Dosimetry, Internal Dosimetry, Biological Dosimetry and Radiobiology. Particular attention was devoted to the medical applications of ionizing radiations.

Technical Services:

The Environmental Radioactivity Group and the Measurement Laboratory conducted the National Environmental Radiological Survey including the monitoring of the areas around the former uranium mining sites and of the *campus* of Sacavém.

The Radioprotection and Radioactive Waste Group performed activities associated to the licensing of

radioactive sealed sources, the interim storage of radioactive waste, the detection of radioactive substances in scrap metal, the management of radioactive wastes on medical, and industrial facilities, and the verification of the radiological safety of installations, among others.

The Dosimetry and Radiobiology Group pursued its technical activities related to the assessment of the safety of radiological installations, mainly in Nuclear Medicine installations and Radiotherapy vaults, in hospitals and clinics throughout the country, as well as to individual and environmental monitoring.

The Laboratory of Metrology of Ionising Radiation performed the calibration and metrological verification of equipments. The available irradiation devices were used in support of R&D activities.

Participation in intercomparison exercises:

The UPSR staff involved in environmental radioactivity measurements and in nuclear analytical techniques and methods participated in intercomparison exercises organized by the European Commission (EC), by the International Atomic Energy Agency (IAEA), by the French IRSN and by Spanish institutions. The UPSR also participated in intercomparison exercises in the fields of Dosimetry (conducted by the Spanish CSN, by EURADOS-European Radiation Dosimetry Group) and Metrology (namely by the IAEA/WHO and the BIPM).

Education and Training:

UPSR researchers participated in training courses in Radiological Protection for professionals in the medical and industrial sectors and taught several disciplines in post-graduation Courses in Radiological Protection and Safety in several Portuguese universities. The number of Master thesis and post-graduation works, by UPSR fellows and/or under the supervision of UPSR researchers, kept increasing. The UPSR participated in the activities of the European platforms and networks in education and training in Radiological Protection, namely EUTERP and CHERNE.

Participation in national and international technical and scientific committees:

UPSR researchers acted as Portuguese representatives and assisted national delegates to international Committees, Working Groups and Task Forces whose activities are organized under the auspices of the EU, the IAEA and the OECD/NEA.

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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.

UPSR Staff

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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;

³ RPII, Ireland;

⁴ formerly NRG, Netherlands;

⁵ ENEA, Italy; ⁶ GAEC, Greece.

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 expect 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 μSv for crew A and 560 μSv for crew B. These values may vary by as much as 110 μSv 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 μSv , 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*, *GSTM1*, *GSTP1*) and genes involved in the repair of DNA damage (*ERCC2*). The combined genotypes *GSTM1**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

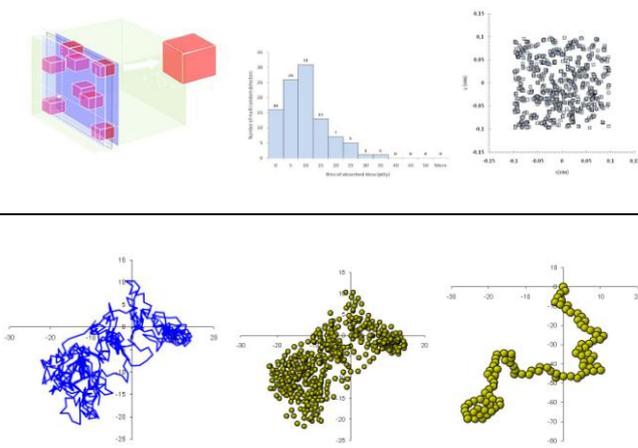
The internal dosimetry activities at the UPSR focused mainly on two topics: activities related to the operation of the Whole Body Counter, and activities related to the participation in several international projects related to the development of new radiotherapy agents. The Whole Body Counter (WBC), 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. 12° 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.

Metrology Laboratory of Ionizing Radiation

Carlos Oliveira

The Metrology Laboratory of Ionising Radiation (LMRI) had been actively involved in activities related to the scientific, applied and legal metrology.

During 2008 efforts have been undertaken to increase the scientific activities and the quality of the services provided to the community.

Concerning the scientific metrology, the LMRI participates in two European projects in the framework of the EURAMET organization:

- as partner in the project entitled “Increasing cancer treatment efficacy using 3D brachytherapy” and
- as collaborator in project “External Beam Cancer Therapy”.

These projects arise from the implementation of the “European Metrology Research Programme” (EMRP) and are co-funded by the European Commission.

Still concerning the scientific metrology, the ITN primary standard for the radiation field of ^{137}Cs , participated in a comparison involving the primary standard at the *Bureau International des Poids et Mesures* (BIPM), Paris, France. This comparison allows the recognition of the equivalence of the Portuguese primary standard to the primary standards of other countries as well as the traceability of the measurements to ITN and a decrease of the uncertainty of the measurements.

In order to expand the LMRI metrological capabilities, to be able to answer to the requirements of the new legislation to be published, the characterization and implementation of the diagnostic radiation qualities according the IEC 61267 standard has been initiated.

The collaboration with other ITN research teams continued, namely with the Radiation 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).

Special attention has been devoted to the collaboration with the University. The LMRI has collaborated with IST (Technical University of Lisbon) and as a result of that, five master thesis) have been concluded and approved. They have been supervised by a member of the Group.

Meanwhile other five master thesis have been accepted by *Universidade Nova de Lisboa* to be performed at the LMRI during the next year.

Concerning the legal metrology 128 dosimeters were calibrated and about 800 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. The annual Internal Audit has occurred at the end of 2008 and the corrective actions will be done during 2009.

One of the members of the team (LS) participate as Manager of the UPSR QS in the Accreditation process which involve the UPSR, also collaborates in the Radiological Protection Programme for UPSR and give support to management of the Data Base of the Environmental Radioactivity Group.

Members of the Group were involved in several committees from EU: Ionising Radiation Technical Committee of EURAMET, Group of Experts of art. 31 (Radiation Protection) and EUTERP.

Research Team

Researcher

C. OLIVEIRA, Princ.

Technical Personnel

J. CARDOSO, graduated technician

L. SANTOS, (50%)

A. CASTRO, technician ITN consultancy contract

Study the Response of an Ionization Chamber

Catarina Simões¹, Margarida Caldeira¹, João Cardoso, L. Santos and C. Oliveira

Objectives

Study the response of an ionization chamber used in Nuclear Medicine by experimental and Monte Carlo simulation methods.

Results

Monte Carlo computer programs such as MCNP have been widely used for simulation of the physical behaviour of the Ionization Chambers (IC) and to obtain correction factors for parameters such as geometry, container type, density and volume of the samples. In this study, MCNP was applied both to determine calibration factors for the radionuclides and the efficiency curve of the IC. The displacement of source position from normal position and its effect on chamber response was studied for most of the radionuclides as well as optimization of the chamber. Monte Carlo simulation calculations were compared with the experimental results.

The measuring system consisted of the Curiementor 2 ionization chamber, from PTW-Freiburg, an electrometer for ionization current measurements and a high voltage supply that provides the chamber with about 1000 V.

The Monte Carlo code MCNP was used to calculate the average energy deposition, E_d , in the gas within the IC per γ ray emitted. The ionization current, I , is given by

$$I = \frac{E_d \cdot p_f \cdot A \cdot e}{W}$$

where A is the activity of the source, p_f the percentage of photons of a given energy emitted by the source, W the average energy required to create an ion pair in the gas and e the electron charge. For argon W is of about 26.4 eV. The calibration factor is given by $C = I/A$, for both experimental and theoretical results, and is expressed in units of pA/MBq.

All the simulations were done using 3×10^5 histories since for this value there was good agreement between relative statistical uncertainty of the MCNP (smaller than 0.2%) and simulation time (maximum of 30 minutes).

The simulated and experimental results for the calibration factors of the radionuclides studied are reported in tab. 1. The uncertainties, with coverage factor $k=1$, are the combined uncertainties of the experimental measurements: for Co-57 its value is 2.74% (expressed as relative uncertainty) and for the remaining radionuclides is 14.14%; for the MCNP simulations, the estimated relative uncertainty of the energy deposition in the argon of the chamber is 5.24%. Overall, there is excellent agreement between simulated and experimental results.

From the displacement studies it could be observed that the response of the chamber decreases with increasing distance of the source to the bottom.

Radionuclide	$C_{exp.}$ (pA/MBq)	C_{MCNP} (pA/MBq)
Co-57	3.60	3.77
F-18	11.38	10.68
In-111	6.38	6.23
I-123	6.02	5.85
I-131	4.65	4.44
Tc-99m	3.15	3.18

Table 1 – Results of the experimental and simulated calibration factors for the radionuclides studied.

So, as referred in the IC's manual, the optimal position for measurements is the source in the bottom of the well. This is due to the small height of the Curiementor 2, resulting in great loss of particles through the opening of the IC.

The sensitivity function, $S(E)$, shown in fig. 1, was obtained by simulation with MCNP. This curve is the convolution of three functions: the number of photons inside the chamber, the mass energy-transfer coefficient and the linear relation between emitted energies and E_d . The influence of the absorption effect of the grids is shown to be very small.

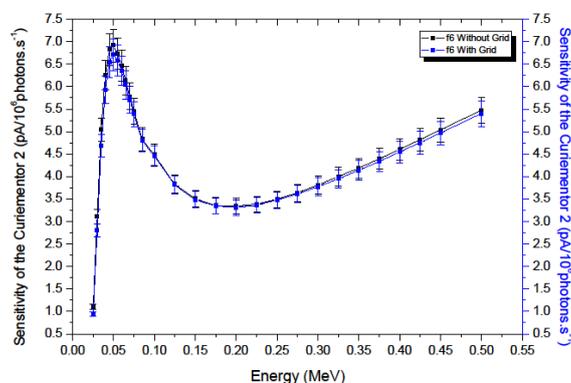


Figure 1 - Sensitivity function $S(E)$ for geometry with grids and without grids.

From the optimization results it can be said that high chambers are more suitable for tests with different types of containers and different volumes of solution, since, for source displacement, the response of these ICs presented very small variations. For larger diameters the efficiency increases, but higher supply voltages would be necessary to sustain the good operation of the chamber, which can be very unfavorable. The Monte Carlo program used in the study proved to be suitable for determination of calibration factors, analysis of the sensitivity function and optimization of the IC's response.

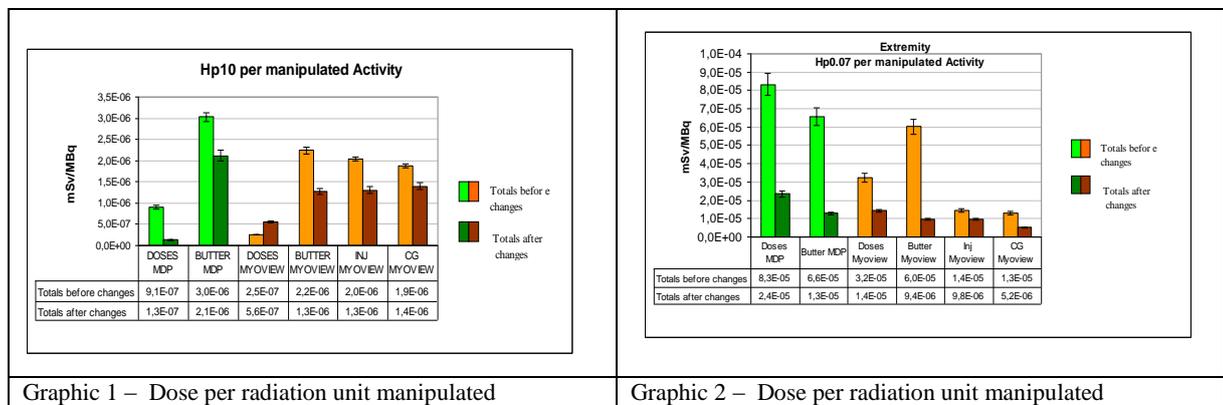
¹ MSc student/IST

Evaluation and Optimization of the Radiation Doses of the Nuclear Medicine Technicians

A. Geão¹; V. Jerónimo¹; P. Colarinha¹; J.G. Alves; A. Calado; M. Neves; C Oliveira

Many procedures used in a Nuclear Medicine service during their daily activity allow the execution of a large number of examinations for diagnosis and therapy. The Nuclear Medicine Technologist (NMT) participates actively in these procedures and is can therefore be subject to a high dose of radiation. The aim of this study was the evaluation and optimization of the exposition to radiation of the nuclear medicine technicians (NMT). This study identifies routine techniques involving the manipulation of high activities, namely: Elution of the 99Mo/99mTc generator; kit preparation of bone and cardiac radiopharmaceuticals; Unit-dose dispensing; administration to the patients and acquiring images. These procedures were monitored with whole-body and extremity dosimeters for a period of 7 months. In procedures where higher values of radiation dose to the NMT were measured, defined strategies for handling practices in order to their minimization were implemented.

The Hp(10) before and after the changes in procedures, is shown in graphic 1 (whole body dosimeter) and the Hp(0,07) is shown in graphic 2 (extremity dosimeter). Graphic 1 and 2 show the Hp(10) and the Hp(0,07) divided by the activity manipulated. Graphic 1 and 2 show that Hp divided by the activity manipulated decreased after changing procedures between 25 to 85% for Hp(10) and 32 to 84% for Hp(0,07). After measuring and comparing the doses of whole body and extremities before and after the change in procedures, we conclude that the changes had a positive impact on doses of radiation received by NMT, reducing them.



¹ Hospital CUF Descobertas

Evaluation of Thermoluminescence Dosimeters for Extremity Monitoring: Monte Carlo Simulation Results

L. Freire, C. Oliveira

The work done using Monte Carlo simulations aimed at assessing if irradiation conditions other than the ones defined in the ISO 12794, 2000 Standard – defined in terms of the object (number and radius of the rod phantoms and irradiation geometry) can alter the air kerma-to-equivalent dose correlation coefficient values, *ha*, which are used to characterize the radiation field.

From the results, we may conclude that the *ha* coefficient can change by as much as 4% when modifying the geometry of the phantom used to simulate the presence of the human body, and 10% when changing the irradiation geometry; variations can be positive or negative, or both, depending on the simulation. These findings suggest that the contribution of the backscattered radiation field can be under- or over- estimated relatively the direct radiation field.

New Metrologic Capabilities at LMRI

J. Cardoso, L. Santos, C. Oliveira

In order to extend the metrological capabilities of the LMRI, in the field of radiodiagnostic, an experimental work of implementation of the radiation qualities according to IEC 61267 standard was initiated. Consequently, it is necessary to characterize the RQR (Radiation Qualities in Radiation Beams) and RQA (Radiation Qualities based on a phantom made up of an aluminium Added Filter) X-ray radiation qualities which implies the determination of the first and second half-value layers (HVL), for all the X ray tube voltages, namely, 40 kV, 50 kV, 60 kV, 70 kV, 80 kV, 90 kV, 100 kV, 120 kV and 150 kV, for the RQR and RQA radiation qualities. The LMRI RQR and RQA radiation characteristics have been determined. The first HVL (mm Al) obtained for RQR2, RQR3, RQR4, RQR5, RQR6 and RQR7 and the first HVL (mm Al) obtained for RQA2, RQA3, RQA4, and RQA5 satisfy the criteria of the IEC 61267 standard.

A Joint research Project to implement the European Metrology Research Programme in the Framework of the Project Imera- Plus

C. Oliveira, J. Cardoso, L. Portugal C. Cruz, L. Santos

Under the Seventh Framework Programme and to implement the “European Metrology Research Programme” (EMRP), the European Commission (EC) co-funds the pilot project iMERA-Plus within the framework of ERANet-Plus for Research and Development (R&D) according to the EC Grant Agreement No. 217257 between the EC and EURAMET e. V (European Association of National Metrology Institutes).

The ITN participate as partner in the Joint Research Project T2.J06 “Increasing cancer treatment efficacy using 3D brachytherapy”.

The aim of the project is to develop methods for the direct measurement of the quantity absorbed dose to water and to extend the use of this reference quantity to brachytherapy dosimetry. The task of the WP were the LMRI is involved is to develop an accurate and convenient procedure to verify the dose distributions in irregularly shaped fields by BT sources in water or a water equivalent phantom. The expected output are suitable portable methods with assessed reliability and accuracy - leading to the target of a dose delivering with an uncertainty less than 5% ($k=1$), at clinical level for the verification of dose distributions for BT sources (e.g., Ir-192 for the treatment of gynaecological cancers and I-125 applied in ophthalmic applicators). This includes the determination of energy and dose response curves of the detection methods, determination of spatial dose distributions around BT sources used in clinical applications, in water or water-equivalent phantoms, supported by Monte Carlo simulations using EGS, PENELOPE, and MCNP codes.

The ITN participate as collaborator in the Joint Research Project T2.J07 “External Beam Cancer Therapy”. This status gives the freedom to participate only when and if possible.

The central objective of JRP7 is to provide a reliable metrology for all radiation based forms of cancer therapy. This includes freshly emerging techniques like High Intensity Therapeutic Ultrasound (HITU) and modern forms of (ionizing) radiation therapy, like Hadron Therapy and Intensity Modulated Radiation Therapy. This JRP is conceived in a way as to draw maximum synergetic advantages from combining two, as yet separate metrological disciplines: ultrasound and ionizing radiation. It is interesting to note that the two disciplines have conceptually a lot in common: radiation is generated, transported through the body with techniques to optimize the impact on cancer.

ITN Air Kerma Primary Standard for ^{137}Cs Key Comparison at BIPM

J. Cardoso, L. Santos, C. Oliveira

Following the 2007 work with the air kerma primary standard, a CC01 graphite cavity ionisation chamber, in the radiation field of Cs-137, it was decided that the ITN primary standard should participate in a comparison at the *Bureau International des Poids et Mesures* (BIPM), Paris, with their primary standard.

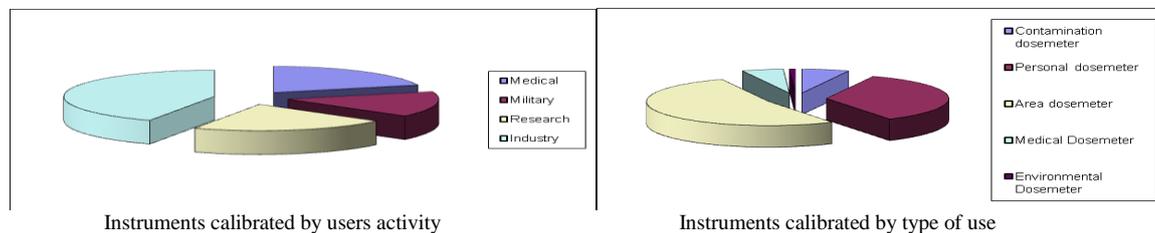
The BIPM acts in matters of world metrology, particularly concerning the demand for measurement standards of ever increasing accuracy, range and diversity, and the need to demonstrate equivalence between national measurement standards.

The main consequences of this comparison exercise are, the recognition of the equivalence of the Portuguese primary standard to the primary standards of other countries, the traceability of the measurements will be to ITN, the uncertainty of the measurements decreased from 0.9% to 0.4% (1σ). These are very positive consequences for ITN.

SERVICES

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

The LMRI provides calibration services mainly for industry, universities, hospitals, armed forces, research organics units of ITN and services of metrological control throughout the country. 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* n°. 423/98. During 2008, 128 dosimeters were calibrated. The following figures group this calibration work by users activity and by type of use.



EXTERNAL SERVICES

LMRI collaboration with INSA group

L. Santos, J. Cardoso, C. Oliveira

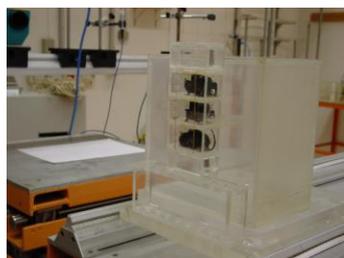
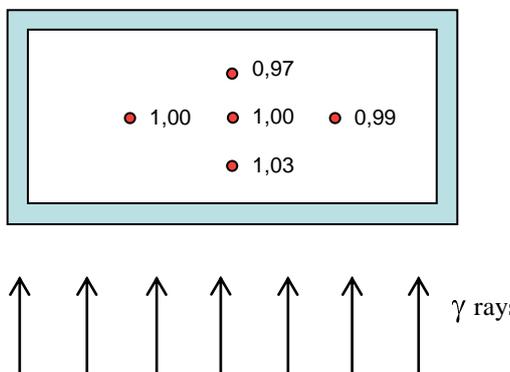


Figure 1: Irradiation position in front of Co-60 source.

The collaboration with INSA (National Institute of Health), in the field of radiobiology, concerns the irradiation of mice in order to induce genetic anomalies. They are irradiated in PMMA boxes in order to maintain a static position during irradiation, as can be seen in figure 1.

In order to optimise the dose to mice, two boxes filled with water were added and positioned in the top and bottom of the mouse boxes. This will provide a uniform dose for all mice in this experimental set up. The absorbed dose inside the central box varies according to figure 2.



According to the relative absorbed doses inside the box, it was decided to irradiate in two-steps, to take this in account. So, after the first irradiation, the box was rotated and the initial face to the radiation is now the posterior face. With this procedure the mice are uniformly irradiated.

Figure 2: Relative absorbed doses inside the box.

INTERNAL SERVICES

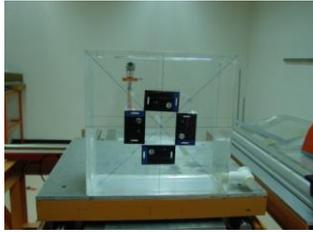
LMRI collaboration with ITN groups

L. Santos, J. Cardoso, C. Oliveira

Portuguese Research Reactor (RPI)

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 ionisation 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.

Radiation Dosimetry and Radiobiology Group (GDR)



Cells and blood irradiation for the UPSR GDR group has been one of the most important collaboration. The samples have been irradiated with several doses of the Co-60 radiation. More than 20 hours of irradiation in Co-60, (about 50 irradiations) has been provided, of all kind of human cells, to their research programs.

Still in collaboration with the UPSR GDR group, about 1000 TLD dosimeters (about 700 for *Hp*(10) and about 300 for *Hp*(0,07)) have been irradiated.

Figure 1: Irradiation of a set of dosimeters

Radiation Technology Unit (UTR)

Measurements in the UTR facility inside the irradiation room and in the maze have been performed. This exercise was done with ionisation chambers, with volumes ranging from 0.6 cm³, 30 cm³, 1000 cm³ and 10000 cm³.

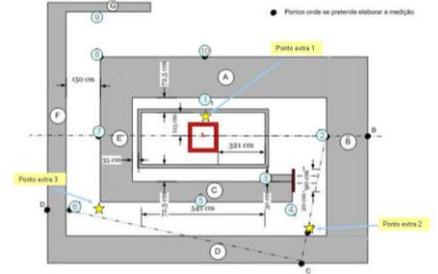
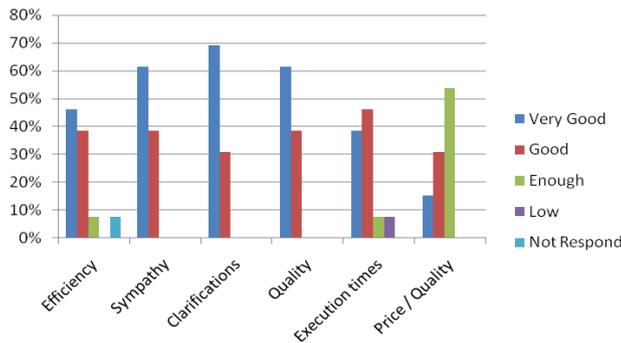


Figure 1: Points position, for experimental measurements, inside the room and maze of UTR.

Quality System

L. Santos, J. Cardoso, C. Oliveira

In order to meet the requirements of the NP EN ISO/IEC 17025:2005 a special attention has been deserved to the Quality System. All 2007 internal audit non conformities have been closed, a new Quality Manual edition has been issued, all administrative procedures have been reviewed and some technical procedures have been reviewed.



has been issued, all administrative procedures have been reviewed and some technical procedures have been reviewed.

Seven non-conformities have been detected and eight recommendations have been proposed by auditors in 2008 internal audit.

A survey has been send to our customers. The following chart displays the survey results.

Environmental Radioactivity

Maria José Madruga

Under Articles 35 and 36 of the EURATOM Treaty, Portugal has an obligation to conduct yearly a national radiological environmental survey. This survey was established in the Decree-Law 138/2005 of 17th August and its execution legally attributed to ITN. The Radiological Environmental Monitoring Programmes have been performed by the Environmental Radioactivity Group in collaboration with the Measurement Laboratories (LM), the Dosimetry and Radiobiology (GDR) and the Radiological Protection and Radioactive Waste Management (GRRR) Groups. To carry out this programme a considerable effort of the group has been made in terms of human resources (about 75% of the time consumed). This programme involves a financial cost of about 348 000 €.

In the framework of the EURATOM Treaty Article 35 the group has been participating in the elaboration of the European Atlas of Natural Radiation. Our contribution consisted in the treatment of the Portuguese indoor radon data to be included in a grid defined by the EC. The processed data were sent to the JRC and a preliminary European map was already delivered.

Current research activities are ongoing to investigate the levels of radioactive contamination in the atmosphere (aerosols) aquatic and terrestrial environments. In the framework of the FCT Project KADRWaste, coordinated by GRRR, the Group participated in the characterization of geomaterials to radiocesium adsorption.

Improvements have been introduced in the technique for alpha/beta measurements in drinking waters using proportional counters and liquid scintillation counting. Quality control tests of recovery and accuracy were performed.

The group participated in coordination with the UPSR/Measurement Laboratory in three international inter-comparison exercises concerning drinking water samples, organized by the European Commission, Institute for Reference Materials and Measurements (IRMM, EC-Joint Research Centre, Belgium), by the Lab. de Radiactividad Ambiental, Universidad de

Extremadura, Cáceres (Spain) and by Institute de Radioprotection et de Sûreté Nucléaire (IRSN), France. The results published in 2008 were in good agreement/compatible with the reference values.

The construction of the infrastructure for housing the Radionuclide Particulate Station (RN53) at S. Miguel, Azores, was concluded last year. The installation of the CINDERELA station and all the related equipment (detector, meteo station, VSAT antenna, etc) was also concluded. A new calibration of the detector with a fresh source was carried out during 2008. A few problems related to the performance of the detector on the low energies region come up resulting in the need of several interventions during 2008. A last intervention is planned for the beginning of the next year and afterwards the station will be ready for certification. This station will be part of the International Monitoring System, established in the framework of the CTBT (Comprehensive Nuclear Test Ban Treaty).

The technical services developed by the group are carried out under contract with companies or, by request from enterprises or Government organizations. Some of these technical services are: the evaluation of the radioactivity levels in public water supplies (Decree-Law nº306/2007) and mineral waters, the radioactivity analyses of foodstuffs and indoor radon measurements. The group income of these technical services was about 31 000 €.

During the current year the majority of the group members have been actively involved in the improvement of the quality system following the ISO 17025 requirements in order to achieve the laboratories accreditation.

One of the tasks of the group is the education and training of staff and young students. During this year two MSc theses were concluded and one was submitted. A member of the group has finished his dissertation (Ph.D. equivalent) was promoted to Researcher.

Research Team

Researchers

M. J. MADRUGA, Princ., Group Leader
F. P. CARVALHO, Princ.
M. J. REIS, Aux.
J. A. CORISCO, Aux.

Students

A. R. GOMES, FCT grant
H. FONSECA, FCT grant
J. MELO, FCT grant

Technical Personnel

J. M. OLIVEIRA (1ª) (70%)
A. LIBÂNIO
A. MOURATO

Collaborators

I. LOPES
M. M. MALTA

Radiological Environmental Monitoring Programmes

M.J. Madruga, F.P. Carvalho, M. Reis, N. Pinhão, J.G. Alves, J.A. Corisco, R. Trindade, J.M. Oliveira, A. Libânio, A. Mourato, G. Silva, L. Portugal, I. Lopes, J. Abrantes, L. Silva, L. Torres, M. Malta, A.R. Gomes, G. Carvalhal, H. Fonseca, J. Melo, M. Pereira, A. Batista

Objectives

The Article 35 of the EURATOM Treaty stipulates that “each Member State shall have the facilities necessary to carry out the continuous monitoring of the levels of radioactivity in the air, water and soil and to ensure the compliance with the Basic Safety Standards”. The Article 36 of the same Treaty stipulates that “the appropriate authorities shall periodically communicate information on the checks referred to in Article 35 to the Commission so that it is kept informed of the level of radioactivity to which the public is exposed”.

The Radiological Environmental Monitoring Programmes planned according to the Articles 35 of the EURATOM Treaty requirements include the Programme at a National Level, established by law in 2005 and the competency of its execution legally attributed to ITN (Decree-Law 138/2005, 17th August), the Source Related Programme for the ITN *Campus* and the Specific Programme for the Regions Around Old Uranium Mining Sites.

The main goals of the radiological environmental survey are to determine the artificial and natural radionuclide levels in environmental compartments (aquatic, terrestrial and atmospheric environments) considered as direct pathways of contamination to man and to evaluate the external radiation levels in order to provide information for the assessment of the potential exposure of the Portuguese population.

The monitoring programme carried out for the ITN *campus* includes measurements of external radiation levels (gamma dose) and measurements of radionuclide activity concentrations in relevant environmental samples (aerosols, rain water and soils). The main objectives of the programme were to verify the compliance with the authorized discharge limits, to check the operation conditions and discharge controls adequacy, to maintain a continuing record on environmental radionuclide levels related to the sources under consideration and to provide information for the public.

The environmental radioactivity monitoring for the regions around old uranium mining sites was implemented in the regions of Viseu and, around the former uranium mining and milling sites of Urgeiriça, Quinta do Bispo, Cunha Baixa, Murtórios, and Barracão. For this purpose three field missions were performed to carry out field measurements and sampling of aerosols, water, soils and plants. Samples were analyzed in the laboratory for the main descendants of uranium by alpha spectrometry. Particular attention was paid to water and agricultural used in human diet in order to assess the exposure of local population to food chain transfer of radionuclides.



Results

During 2008 about 800 samples (aerosols, rainwater, surface water, drinking water, sediments, fish, mixed diet, complete meals, milk, soils, etc.) were collected accordingly to international sampling procedures and a total of about 2700 analyses were performed for the determination of artificial and natural radionuclides, using gamma and alpha spectrometry, alpha/beta measurements and liquid scintillation technique. Integrated measurements of the ambient dose equivalent with thermoluminescent dosimeters were also performed. The results show that the Portuguese population was not exposed to radioactive contamination levels higher than the radioactive background. Therefore, there is no need to adopt any measures for radiological protection of the population. All the data are published in Internal Reports (1) made available in the ITN website (<http://www.itn.pt>) and included in the European Radioactivity Environmental Monitoring Database (REM) located at the EU Joint Research Centre, ISPRA (Italy).

Published work

M. J. Madruga, F. P. Carvalho, M. Reis, N. Pinhão, J. Alves, J. A. Corisco, R. Trindade, J.M. Oliveira, A. Libânio, A. Mourato, G. Silva, L. Portugal, I. Lopes, L. Silva, J. Abrantes, L. Torres, A.R. Gomes, G. Carvalhal, H. Fonseca, J. Melo, M. Pereira, A. Batista. *Programas de Monitorização Radiológica Ambiental (Ano 2007). Internal Report DPRSN, Série A, nº32/2008, ISBN 978-972-8660-33-8, Depósito Legal 194022/03, pp. 147.*

Biomass Combustion and Release of Radionuclides into the Atmosphere

F.P. Carvalho, J. M. Oliveira

A collaborative project with University of Aveiro, funded by FCT, was started to evaluate the release into the atmosphere of several contaminants including organic substances, toxic metals and radionuclides. The extension of forest fires in Portugal as well as around the entire Mediterranean basin is a non negligible source of toxic substances and contaminants, including natural radionuclides and artificial radionuclides deposited on surface soils following the Chernobyl accident. Several experimental approaches were assessed including measurements during true forest fires, measurements during small scale programmed fires, and laboratory burning of biomass. A prescribed forest fire in the mountains, near Góis, was jointly organized with Escola Agrária de Coimbra and Serviços Florestais to allow for field measurements.

Development and Validation of Radioanalytical Methods using Liquid Scintillation Counting (LSC) Technique

M.J. Madruga, I. Lopes, J. Melo

The Liquid Scintillation Counting (LSC) is a technique widely used for measuring radiation from beta and alpha emitting radionuclides. Following the application of this technique, at the GRA Laboratories, to the determination of ^{90}Sr in milk based on the use of ion exchange chromatography (Sr resin, Eichrom), validation trials were performed in order to implement the same method to foodstuffs samples. The recovery of the method to these matrices, defined as the ratio of ^{90}Sr activity measured and ^{90}Sr activity added, was evaluated and a recovery value of 88% was obtained. This methodology was tested to foodstuffs samples within the radiological environmental monitoring survey. In the framework of the quality control and in order to improve the global alpha and global beta measurements by LSC, calibration and recovery tests in waters were also carried out.

Transport and Accumulation of ^{137}Cs and ^{90}Sr by the Unicellular Microalgae *Chlamydomonas reinhardtii* Dangeard

J.A. Corisco, J. Fernandez¹

The present state of the art in the field of ion transport supports the hypothesis that $^{137}\text{Cs}^+$ and $^{90}\text{Sr}^{2+}$ free ions in water are accumulated by the unicellular microalgae *C. reinhardtii*, as a result of a transmembrane transport mediated by the mechanisms involved in the transport of K^+ and Ca^{2+} ions through the plasma membrane. Experimental objectives were (i) to verify the effects of external concentrations of K^+ , Ca^{2+} , Na^+ and H^+ on the transport and accumulation of $^{137}\text{Cs}^+$ and $^{90}\text{Sr}^{2+}$; (ii) to characterize the uptake kinetics of Cs^+ and Sr^{2+} under deficiency and sufficiency of K^+ ; (iii) to verify the effect of K^+ and Ca^{2+} channel blockage with specific inhibitors, namely tetraethylammonium (TEA^+) and La^{3+} ; and (iv) to verify the effect produced by the inhibition of plasma membrane H^+ -ATPase with cyanide (CN^-). The obtained results reveal the presence of two different mechanisms mediating the transport of $^{137}\text{Cs}^+$. An active uptake mechanism with Michaelis-Menten type kinetics and a relevant sensibility for pH is induced by K^+ deficiency, whereas under K^+ sufficiency $^{137}\text{Cs}^+$ undergoes a passive transport through ion channels. Such observations support the hypothesis that K^+/H^+ co-transporters and K^+ channels are mediating the transport of $^{137}\text{Cs}^+$ in *C. reinhardtii*, according to the external K^+ regime. $^{137}\text{Cs}^+$ concentration factor (CF) reached the value 48388 in K^+ deficiency and 4568 in K^+ sufficiency. Uptake of $^{90}\text{Sr}^{2+}$ is likely to be mediated by Ca^{2+} channels, with more intense fluxes through channels activated by hyperpolarization of the cell membrane, when external K^+ concentration is within the micromolar range. The observed $^{90}\text{Sr}^{2+}$ CF for cells in K^+ deficiency reached the maximum value of 10755 in an alkaline medium of $\text{pH}=8.3$. Cells under K^+ sufficiency showed maximum $^{90}\text{Sr}^{2+}$ accumulation ($\text{FC}=2309$) in a medium with physiological $\text{pH}=7.3$. It is likely that changes in pH to more acidic and alkaline values intensify the extrusion of $^{90}\text{Sr}^{2+}$ via the Ca^{2+} -ATPase, thus reducing the value of FC.

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Marine Radioactivity

F.P. Carvalho, J. M. Oliveira, M. Malta

Research and monitoring of radioactivity in marine organisms was carried out in order to pursue the assessment of radiation doses from naturally-occurring and man made radionuclides. Monitoring of radionuclides along the Portuguese coast was performed using mussels as bioindicator organisms collected at various sites on the open coast and in the main harbours. Determination of radionuclides in mussels, fish and marine mammals (dolphins) was used to compute radiation doses to biota and it is part of a Master Thesis (M Malta).

Indoor Radon Risk Mapping*M.J. Reis, H. Fonseca*

A new approach is being implemented in order to obtain indoor radon risk maps by using geostatistic simulation techniques. Besides the radon data already available for Portugal, new data were processed. Indoor radon distribution maps were developed for Portugal, namely prediction and probability maps (for example the probability map of exceeding 400 Bq m⁻³). After data processing several methods will be investigated for the establishment of risks categories and radon mapping. Geographical Information Systems (GIS) techniques are being used to integrate radon concentrations, geological and administrative maps, buildings locations and other useful information. In collaboration with the REM (Radioactivity Environmental Monitoring) group of the JRC (Joint Research Centre) a European Atlas of Natural Radiation, including radon mapping is being developed. The Portuguese indoor radon data was processed and transformed in order to fit the European grid defined by the JRC. A preliminary European indoor radon map was constructed and presented in the *9th International Workshop on the Geological Aspects of Radon Mapping* (as part of the 33rd International Geological Congress), held in Oslo in August 2008.

SERVICES**1. Radioactivity in Drinking and Mineral Waters***M.J. Madruga, J. Melo, A.R. Gomes, A. Libânio, I. Lopes, F.P. Carvalho, J.M. Oliveira*

Regarding the evaluation of the radioactivity levels in drinking waters (Decree-Law n°306/2007) the UPSR was requested by Water Suppliers to carry out the determinations of global alpha, global beta, Tritium, ²³⁸U, ²³⁴Th, ²²⁶Ra and ²¹⁰Po and the Total Indicative Dose parameter in waters. The determination of Radon in same water samples was also carried out. To license the mineral waters trade an evaluation of its radioactive levels should be performed (Decree-Law n°84/90). The radiological study included analyses of ²²⁶Ra and global beta. Several enterprises often request this radiological study.

During 2008, a total of about 450 analyses were performed.

2. Radioactivity in Surface and Ground Waters*M.J. Madruga, J. Melo, A.R. Gomes, A. Libânio*

The alpha/beta global activities and the tritium levels in water samples were determined within FCT-KADR Waste project in collaboration with GRRR group.

2. Indoor Radon*M.J. Reis, H. Fonseca*

By request of public and private enterprises indoor radon measurements were performed in buildings. Since November 2003 a collaborative Protocol was established between UPSR-ITN and DECO to answer the associate's indoor radon requests. A total of 120 measurements were performed during this year.

Radioprotection and Radioactive Waste

Romão Trindade

The Radioprotection and Radioactive Waste Group (GRRR) has pursued in 2008 R&D activities with its involvement in the KADRWaste Project, in collaboration with Portuguese academia (Faculty of Sciences-U. Lisbon, Faculty of Sciences-U. Porto, U. Évora and ITN/Chemistry Unit). This Project has started in January, 2008. Still in terms of R&D, the GRRR and the Chemistry Unit of ITN, are involved in the European IP ACSEPT (“*Actinide Recycling by Separation and Transmutation*”) approved under the Euratom FP7-Fission-2007 Framework Program and started in March. Also in 2008, negotiations were initiated concerning ITN’ participation in PETRUS II (FP7) and GEOSAF (IAEA) projects.

Concerning Education & Training, a member of the Group has finished a Masters Degree thesis in Safety and Radiological Protection at (IST-Technical University of Lisbon), another member continued his work in the framework of a PhD degree in the field of radioactive waste management in collaboration with FC/UL (Faculty of Sciences, U. Lisbon). Two Post Graduation Thesis in Applied Geology were completed in collaboration with Faculty of Sciences of U. Lisbon (Department of Geology). A final year degree thesis in Environmental Engineering in the area of scrap metal as radioactive waste was also finished in collaboration with “Universidade Lusófona de Humanidades e Tecnologias”. Members of the GRRR have participated as lecturers and invited professors in high-level education activities: Advanced Post-Graduation Studies (DFA) on “Safety and Radiological Protection“. They have also participated in several professional training courses, in-house through the Training Centre and upon external request.

Members of the Group were also involved in several committees, working groups and task forces from the

EU, IAEA, OECD, OSPAR, CTBTO and national groups.

Considering the activities related to legal obligations such as licensing of sealed sources for medical, industrial, teaching and research applications, the Group has issued 454 licensing requested for analysis and authorization during 2008. Also during the last year and still considering legal obligations, about 156 requests for collecting and storing radioactive waste were received and processed.

Twelve events related to the detection of radioactive substances in scrap metal were carried out by GRRR during 2008. In terms of radiological protection and safety verifications, the GRRR has carried out eight actions at medical, military vessel and recycling facilities.

The Monitoring Programme of the radioactive liquid discharges from public and private nuclear medicine services into the public sewage of Lisbon was continued in 2008, in collaboration with Lisbon Borough City Council (CML).

The ITN Monitoring Programme in compliance with Articles 35° and 36° of the Euratom Treaty has been pursued with the setup of the ECoDELiR (Estação de Controlo das Descargas dos Efluentes Líquidos Radioactivos), to monitor all radioactive liquid discharges of ITN *Campus*. At the end of the 2008, work has started in order to renew and improve the ECoDELiR infrastructures.

Still in the framework of the aforementioned Euratom Articles, the *Campus* environmental gamma radiation dose has been assessed through the gamma monitoring network, GAMMANET, with detectors located in three strategic points of the Campus operated and maintained by this Group.

Radioprotection and radioactive waste staff

Researchers

R. TRINDADE, Aux., Group Leader
M. I. PAIVA, Aux.

Technical Graduate

L.M. PORTUGAL

Technician

J. VENÂNCIO

Collaborators

P. DUARTE
A. BAPTISTA
P. SANTOS (until Sep. 2008)
F. MAIA (until Jul. 2008)
C. BETÂNIA (until Jun. 2008)

KADRWaste – Study of the Adsorption Mechanisms and Kinetics in Geomaterials and Their Structural Characterisation: Implications for Processes of Natural Attenuation of Heavy Metal Contamination and Radioactive Wastes Confinement

M. Abel¹, A. Mateus¹, I. Bobos², I. Paiva, R. Trindade, P. Duarte, N. Pinhão, M. F. Araújo, J. Mirão³ et al

This project (PTDC/CTE-GEX/82678/2006) has started in January 2008 and aims at providing integrated knowledge on the adsorption/desorption mechanisms and kinetics of both heavy metals (Cu, Zn) and radionuclides (¹³⁷Cs, ⁹⁰Sr, ²⁴¹Am, and ²³⁸U) onto clay minerals and sapropels from the micro to macroscopic level. The objective is to will be such as to reflect natural environments and to propose remediation strategies integrated in radioactive waste confinement solutions. Special attention will be paid to interactions between metals and substrate, including

surface complexes, surface sites, sorption equilibrium and ion speciation. Sorption efficiency by means of kinetics of adsorption/desorption will be done for the long-term stability of metals. Assessment of adsorption competition between some radionuclides and these metals and the effects of radiation-induced damage on clay surfaces will be essayed. Radiological characterisation of sites for the long-term radioactive waste repository as an important step for monitoring actions will be performed.

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²(ADFC/Geology/FC/UP),

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ACSEPT-Actinide reCycling by SEParation and Transmutation (7th Programme EURATOM- FP7-Fission2007)

I. Paiva, J. Marçalo, P. Vaz, R. Trindade

Actinide recycling by separation and transmutation is considered worldwide and particularly in several European countries as one of the most promising strategies to reduce the inventory of radioactive waste, thus contributing to make nuclear energy more sustainable. The ACSEPT Consortium (FP7-Euratom Fission) has started in March of 2008 and ITN preliminary experimental results are already available. The overall objective in this project is to study the kinetics and energetics of the association reactions of Ln(III) and An(III) ions with ligands effective in Ln/An separations and in use within ACSEPT, by means of mass spectrometry techniques. An experimental methodology has been setup to carry out studies of the gas-phase reactivity of Ln(III) and An(III) ions with ligands provided by ACSEPT partners, using FT-ICR mass spectrometry.

In the FT-ICR/MS technique, metal ions generated by laser desorption/ionisation (LDI) are injected and confined in the ICR cell, where they are selected and collisions with neutral species can occur. Resulting reactions can be monitored with time and the ionic species formed can be detected. The main feature of gas-phase reactions is that, especially at low pressure, the physical and chemical properties of ionic species can be studied in the absence of disturbing factors such as the solvent and lattice inherent to the condensed phases (solution or solid). Ion-molecule reactions in the gas phase can be up to two orders of magnitude faster than in solution due to the long-range attractive forces that confer enough energy to the ion-neutral complex to quickly proceed to the reaction products.

Preliminary studies of the gas-phase association of the Me-BTBP ligand (from CEA) with Gd(III) and Cm(III) as MCl_2^+ ions were performed. The experiments were carried out using a Finnigan FT/MS 2001-DT FT-ICR mass spectrometer, equipped with a 3 T superconductivity magnet, a Spectra-Physics Quanta-Ray GCR-11 Nd:YAG laser (1064 nm) and a Finnigan Venus Odyssey data system. The formation of the MCl_2^+ ions from the reactions of M^+ or MO^+ with CH_2Cl_2 was studied in detail. These gas-phase reactions have not been studied previously and bear interest in themselves for gas-phase f-element chemistry. The kinetics of reactions 1-3 was studied and the reaction efficiencies (k/k_{COL}) determined was as follows: Gd^+ (45%), GdO^+ (6.5%), Cm^+ (39%), CmO^+ (24%). Experimental procedures are being optimized.

In the ESI-QIT/MS technique, metal ion complexation in solution can be probed. Very preliminary studies with the Me-BTBP and TEMA ligands (from CEA) in solution, to study the competitive complexation with Pr, Nd and Sm (as the nitrates) and the effect of ionic radii, were carried out, using a Bruker HCT ESI-QIT mass spectrometer.

Characterization of Suitable Areas for a Long-Term Radioactive Waste Repository Facility in PortugalP. Duarte, I. Paiva, A. Mateus¹, R. Trindade

The work in progress is part of a PhD thesis being carried out in collaboration with Department of Geology/FCUL. Following a preliminary study, two specific potential suitable areas to host near-surface repositories (geologically composed by peridotites and schists), have been chosen to be characterized in more detail. Radiological mapping of both areas was performed, using a based Geographic Information System and gamma radiation data from 980 measuring points along several profiles. These data was obtained with portable NaI (Tl) gamma detectors. Statistical treatment of the data (interpolation by kriging) obtained from the radiometric profiles pointed out significant and representative sampling locals. In these locals, soils (through vertical profiles in three different depths), rocks, and vegetable covers were collected and were taken to the lab for ongoing analysis by various techniques: Gamma spectrometry for the identification and quantification of natural and artificial gamma emitters (total sample and fraction $<63\mu m$); XRD for mineralogical analysis (with emphasis on granulometric fraction $<10\mu m$ due to the importance of clay minerals in radionuclide retention processes). Organic matter content was also quantified in soil samples and, rock samples mineralogy is in progress.

Studies of the $<63\mu m$ soil fraction adsorption capacity for radionuclides, mainly ^{137}Cs , have started (with the involvement of Group of Environmental Radioactivity of DPRSN). ED-XRF analyses were carried out with the collaboration of the Environmental Analytical Chemistry Group of the ITN's Chemistry Department; Gamma Spectrometry studies were developed in collaboration with the Measurement Unit of ITN's DPRSN; FT-IR measurements were performed in the Department of Geology of FCUP.

¹ Dept. Geologia, FCUL

SERVICES

1. Radioactive waste management

During 2008 about 156 requests for radioactive waste collection were received and carried out. These radioactive wastes were collected, segregated, transported for interim storage at the “Pavilhão de Armazenamento Interino de Resíduos Radioactivos”, (PAIRR) located at ITN *Campus*. In this year only one (1) technician is working at PAIRR, which is not enough to carry out all present duties. It is very important and urgent to define and to establish a national plan related to radioactive wastes produced in Portugal, according international directives.

2. Sealed sources licensing

According Decree-Law n° 38/2007 and Decree-Law n° 165/2002, 454 sealed sources licensing were issued: national territory introduction licences (150), transfer licences (47), transport licences (90) and ownership licences (167). Only one person is related with this activity.

3. Gamma Monitoring Network (GAMMANET) of Instituto Tecnológico e Nuclear (ITN)

The environmental dose gamma radiation at ITN *Campus* is continuously being measured by the gamma network, GAMMANET. The data are collected, analysed and reported to the EU, according to articles 35° and 36° of the Euratom Treaty. During 2008 the network was reviewed and calibrated at Germany.

4. Radioactive liquid discharges from Instituto Tecnológico e Nuclear (ITN)

Radioactive liquid wastes originated at ITN are analysed and measured at “Estação de Controlo das Descargas dos Efluentes Líquidos Radioactivos” (ECoDELiR) before being discharged into Estação de Águas Residuais (ETAR). The data are reported to the EU according Articles 35° and 36° of Euratom Treaty and to the Radioactive Substances Committee of OSPAR Convention. By the end of 2008, the work to repair and to improve ECoDELiR has started.

5. Radioactive liquid discharges from Instituto Português de Oncologia (IPO), Coimbra

In 2008 and as requested by IPO-CROC, EPE, Coimbra, the radiological survey of radioactive liquid effluents from the IPO's Medicine Nuclear Retention Tanks, was carried out by the Group before discharge into the public sewage.

6. Nuclear vessels radiological monitoring

In 2008, two nuclear vessels stayed at Portinho da Costa harbour and estuary of Rio Tejo. Environmental radioactivity survey programmes consisting on continuous monitoring of radioactive aerosols and airborne radioiodine, sampling of water, sediments and biological species for gamma spectrometry analysis were carried out. Sampling was done before, during and after the stay of the vessel. Reports were sent to Ministry of Defence.

7. Radioactivity in scrap metal

In 2008, and as result of radiological surveys requested by the smelting industry, twelve events related to the detection of radioactive materials in scrap metal at smelting factories have been reported. The material collected has been stored at Pavilhão de Armazenamento Interino de Resíduos Radioactivos, (PAIRR) as radioactive waste. Reports were sent to the smelting company.

8. Radiological protection and safety verifications

During 2008, GRRR has carry out six verifications concerning radiological protection and safety at medical facilities, in collaboration with GDR. Two radiological monitoring actions were carry out in a military vessel and in a recycling facility.

9. Radioactive Liquid Discharges from Hospitals in Public Sewage of Lisbon Borough Council (CML)

Radioactive liquid discharges from private and state owned nuclear medicines in Lisbon public sewage as well as residual effluents from Lisbon's four Water Treatment Plants (ETARs), have been monitored by UPSR/ITN in 2008. Sampling was carried out in order to identify the radionuclides present and their activities. About 100 samples of liquid effluents were collected and analysed by quantitative and qualitative gamma spectrometry. This monitoring programme, requested by CML, was divided in two different programmes. Programme I involved sequential collection of 4 discrete samples in 5 sampling points from nuclear medicine facilities. In Programme II, 4 discrete samples were taken at one single discharge point of each Lisbon's ETARs.

Measurement Laboratories

*Mário João Capucho dos Reis**

The Measurement Laboratories (ML) provide analytical services in the area of radioactive control of low and medium activity samples and in measurement of ions in liquid samples.

Together with the Environmental Radioactivity Group (GRA), which is responsible for collection, chemical preparation of the samples and data organization), the ML carries out Portugal's obligations under Article 35 of the EURATOM Treaty which requires member states to conduct national environmental radiological survey annually.

The ML is also involved in research work and provides external analytical services to support industrial and commercial activities.

The techniques used are high resolution gamma-ray spectrometry; gross alpha/beta counting and beta counting of specific radionuclide using gas flow proportional counters; liquid scintillation and alpha spectrometry. Ion chromatography is also used to assist in the evaluation of the residual beta activity and in characterization of liquid samples.

In 2008 the range of radioactivity measurement services provided includes:

- Assessment of occupational exposure to ^{125}I and evaluation of the effective dose of ITN workers;
- Analysis of radioisotopes in water to assist in the surveillance of ITN's research reactor;
- Control of foodstuff, export or import products and building materials;
- Analysis of gross alpha/beta and ^3H activities in drinking water (in collaboration with the GRA);
- Measurement of ^3H in biological samples by liquid scintillation for cancer research; and
- Alpha spectrometry on water and soils samples.

In 2008 ML was involved in the following research projects:

- Project *KADRWaste*, involving gamma spectrometry and ion chromatography (a new ultra-low background HPGe detector was acquired on the framework of this project);
- Collaboration with the Aveiro University on the geochronology of sediments using nuclear techniques.

During this year, a plastic scintillator was acquired in order to implement an active background reduction technique (veto detector for the ultra-low background detection system) on the gamma spectrometry laboratory.

During 2008 the ML participated in several intercomparison exercises with good results.

Finally, the staff from the ML was actively involved in the preparation of the accreditation process of the radioanalytical techniques, according to the ISO/IEC 17025 standard, namely the:

- Definition of procedures and organization of equipment records;
- Participation on the "Technical and Management Requirements" working groups, and;

Regarding the training and education, during 2008:

- One group member initiate a post-graduation training programme (DFA) on Radiological Protection and Safety, at IST (Technical University of Lisbon);
- A student from the FC/UL (Faculty of Sciences, University of Lisbon) finished the final-year training in Physics in the ML.

Research Team

Researchers

*M. REIS (from June), Aux.

Analysis Contractors

L. SILVA, physicist

J. ABRANTES, physics engineer

L. TORRES, chemical engineer

Technical Personnel

J.M. OLIVEIRA, Senior Technician (30%)

G. SILVA, Technician [1^a]

Informatics Consultant

J.P. SARAIVA (until June)

Students

G. CARVALHAL, FCT grantee

R. MENDES, FC/UL graduation student (until September)

Geochronology of sediments using nuclear techniques

L. Silva, N. R. Pinhão

Objectives

During four decades (1950-1994), Ria de Aveiro was subject to continuous discharges of mercury-rich effluents from a plant located in a chemical complex industry upstream.

Vertical profiles of mercury concentrations of salt marsh sediments colonized by plants and sediments without vegetation of Laranjo Bay (a semi-enclosed bay) shows a sub surface maximum at different depths along the contaminated bay. The main objective of this work was the study of sediment chronologies based on ^{210}Pb and ^{137}Cs profiles in order to correlate the peak of mercury concentration with the industrial activity.

Results

The ^{137}Cs data show a maximum around 30-40, 20 or 50 cm respectively for stations A, B and C identifiable with the Chernobyl accident of 1986 and very close to the maximum of mercury concentration in each station. Assuming a constant sedimentation rate, we can make a first estimate of the sedimentation rates in 1.43-1.9, 0.95 and 2.38 cm/yr respectively for stations A, B and C.

Except for the first value in stations A and B, the unsupported ^{210}Pb values show a relatively smooth behavior. Also shown are the regression lines obtained

using an exponential model with weighted uncertainties but neglecting the first value in stations A and B. Using the CRS model the sedimentation rates are (1.25 ± 0.41) cm/yr, (0.88 ± 0.49) cm/yr and (2.24 ± 1.01) cm/yr respectively for stations A, B and C. Although the relative uncertainty is high in all cases, the values are consistent with the previous estimates from the ^{137}Cs data and the mercury observations.

The study of ^{210}Pb and ^{137}Cs profiles has provided chronostratigraphic information consistent with previous estimates from mercury profiles and the known history of the industrial activity in the area. It was confirmed that the area of station C exhibits the highest sedimentation rate, followed by station A.

Published Work

M.Válega, L. Silva, N. Pinhão, A.I. Lillebø, E. Pereira, A.C. Duarte and M.A. Pardal, Historical reconstruction of mercury contamination in Laranjo bay, Proc. of the International Conference on Radioecology & Environmental Radioactivity, 15-20 June 2008, Bergen, Norway

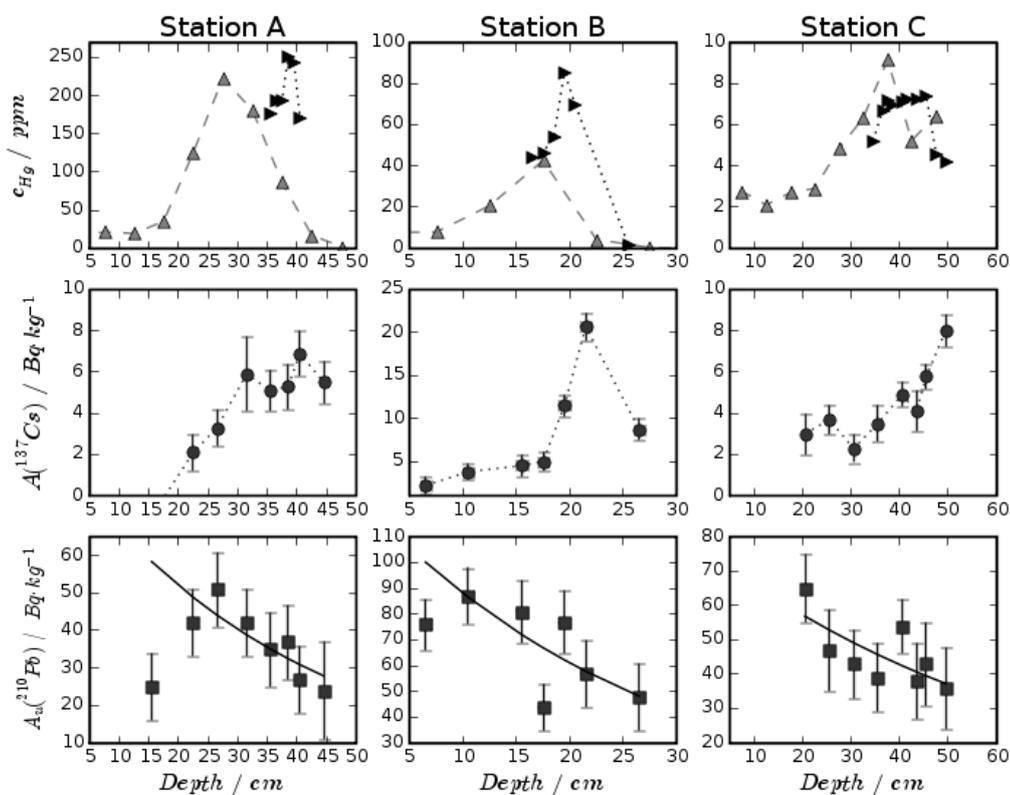


Fig. 1. Subsurface distribution of Hg and ^{137}Cs and ^{210}Pb activity in the three sampling stations

¹²⁵I measurements for occupational exposure assessment

L. Silva, N. R. Pinhão

In order to assess the level of occupational exposure, individual monitoring of workers handling ¹²⁵I was carried out by using high resolution gamma spectrometry. X-ray and gamma spectra of urine samples were analyzed and the K_α and gamma peaks were used to quantify the activity of the samples in order to estimate the committed effective dose by inhalation of ¹²⁵I. For a 24-hour excretion period the committed effective dose was estimated to be less than 0.3 μSv.

SERVICES

Analytical Services on Radioactivity Measurement and Liquid Ion Chromatography

J. Abrantes, G. Carvalhal, J. M. Oliveira, N. R. Pinhão, M. Reis, L. Silva, G. Silva, L. Torres

In 2008, around 4000 analysis have been performed (excluding analysis for calibration, quality control and intercomparison exercises) involving the following techniques: alpha spectrometry (40%), total alpha or beta counting techniques (12%), gamma spectrometry (30%), liquid scintillation (15%), and ion chromatography (3%). The above mentioned analysis were carried out in the framework of the national environmental radiological survey, as services for external entities and for research projects, either of UPSR or other ITN sectors. The services provided to external entities represent a net income for ITN of over 90 kEuros.
