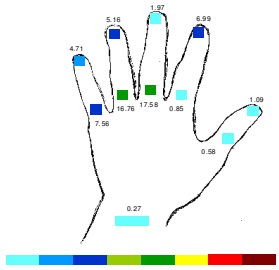
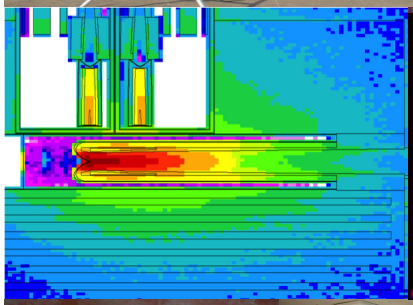
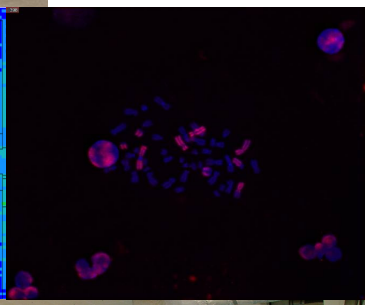
Radiological Protection and Safety Unit







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.

During the first three quarters of 2009 a major effort was undertaken in order to prepare the submission – accomplished in October – of the request to the Portuguese Institute for Accreditation (IPAC) for the accreditation of 8 radioanalytical, dosimetrical and metrological techniques in use at the laboratories of the UPSR. The audits for accreditation should take place during 2010.

An ICP-MS ("Inductive Coupling Plasma Mass Spectrometry") was purchased during 2009 and should become operational during 2010, allowing a simpler, faster and more complete assessment of radionuclides in environmental and biological samples. It is aimed at extending the range of services provided and to improve the preparedness of response of the UPSR in emergency and accidental situations.

As reported in recent years, the persistently increasing 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 (both in the E.U. 6th and 7th Framework Programmes, 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 and consolidate the activities of the UPSR in areas such as Computational Dosimetry, Internal Dosimetry, Biological Dosimetry and Radiobiology.

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 was involved in environmental radioactivity measurements and in nuclear analytical techniques and methods participated in intercomparison exercises organized by the IAEA, by the Spanish Nuclear Safety Council (CSN) and by the National Physical Laboratory (NPL, UK).

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 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 under the auspices of the EU, the IAEA and the OECD/NEA.

Staff

Researchers

P. VAZ, Princ.
F.P. CARVALHO, Princ.
.M.J. MADRUGA, Princ.
M.B. MARTINS, Princ., (until Oct.)
M.A. NEVES, Princ.
C. OLIVEIRA, Princ.
J. ALVES, Aux.
J. CORISCO, Aux.
O. GIL, Aux.
A. D. OLIVEIRA, Aux.
I. PAIVA, Aux.
M. REIS, Aux.
R. TRINDADE, Aux
P. TELES, Aux. (Contract)
M. GOULART, Aux. (Contract. until March)

Technical and Admin. Personnel

J. CARDOSO
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L. PORTUGAL
G. L. SILVA
D. ALVES
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L. SANTOS
M. A. LIBÂNIO
M. E. PACHECO
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M. SARAIVA
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Fellows and Collaborators

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Metrology Laboratory of Ionizing Radiation

Carlos Oliveira

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Research Team

Researcher
C. OLIVEIRA, Princ.

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

Fellow
A. CASTRO, technician ITN consultancy contract

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

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

Objectives

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

Results

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

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

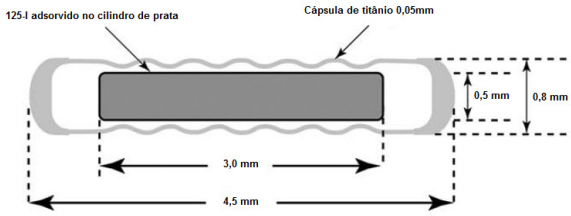

Fig.1 EchoSeed 6733.

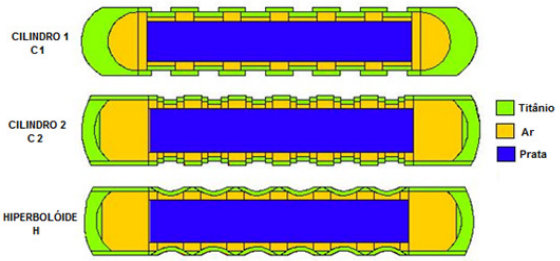

Fig.2 Representation of the three geometries used in this work to model the seed EchoSeed 6733 and their respective materials.

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

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

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

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

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

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

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

[1] FCT-UNL

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

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

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

[1]FCT-UNL

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

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

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

[1]FCT-UNL

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

C. Santos[1], C. Oliveira

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

[1]FCT-UNL

Dose mapping around radiation devices used in industry: a tool for radiation protection purposes
R. Costa[1], C. Oliveira

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

[1]FCT-UNL

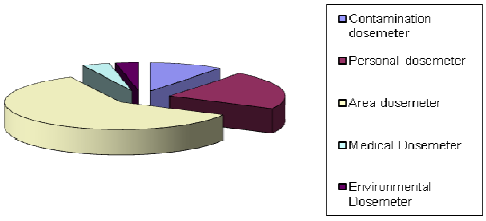
Quality System
L. Santos, J. Cardoso, C. Oliveira

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

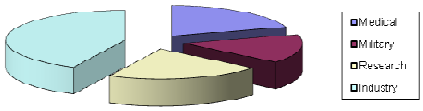
Services

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

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



Instruments calibrated by users activity



Instruments calibrated by type of use

External Services

LMRI collaboration with INSA group

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

LMRI collaboration with FF-UL group

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

Internal Services

LMRI collaboration with ITN Groups

Unit of Reactors and Nuclear Safety (URSN)

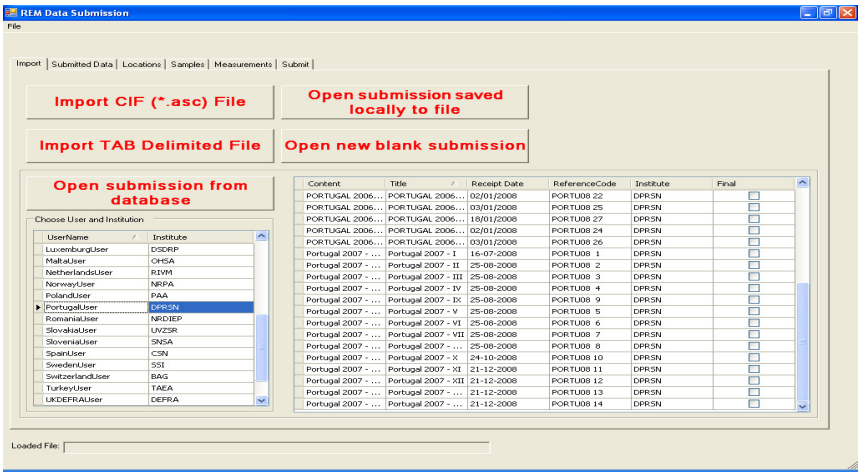
The LMRI performs, every year, in the RPI maintenance period, the metrological control of installed detectors and associated instrumentation of the RPI radiological protection system. This includes the hand-foot contamination monitor, MAB HFM 2102; the area monitors measuring system MGP C/EIP 51 with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

Dosimetry and Radiobiology Group

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

Environmental Radioactivity Group

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



Environmental Radioactivity

Maria José Madruga

One of the main activities of the Environmental Radioactivity Group was to perform the Radiological Environmental Monitoring Programmes in collaboration with the Measurement Laboratories (LM), the Dosimetry and Radiobiology (GDR) and the Radiological Protection and Radioactive Waste Management (GRRR) Groups. These surveys were established according to Articles 35 and 36 of the EURATOM Treaty Recommendations and its execution legally attributed to ITN (Decree-Law 138/2005 of 17th August). To carry out these programmes a considerable effort of the Group has been made in terms of human resources (about 75% of the time consumed). This programme involved a financial cost of about 343 000 €.

Current research activities are ongoing to investigate the levels of radioactive contamination in the atmosphere (aerosols) aquatic and terrestrial environments. In January- February 2009, the Group participated in collaboration with other institutions, in the elaboration of seven research projects submitted to the FCT (Portuguese Foundation for Science and Technology) funding. Only one project was financed concerning the radioactivity in the atmosphere.

The Group participated in collaboration with the Measurement Laboratories in five international inter-comparison exercises: two concerning the determination of natural and artificial radionuclides in drinking water samples, organized by the IAEA/ALMERA and by the Laboratorio de Medidas de Baja Actividad, Universidad de País Vasco, Bilbao (Spain); two for the determination of alpha and gamma emitters in phosphogypsum organized by the IAEA/ALMERA and the CSN (Consejo de Seguridad Nuclear), Spain; and, one concerning the determination of gamma emitters in simulated filters organized by the IAEA/ALMERA. The results published in 2009 were in good agreement/compatible with the reference values.

Regarding the indoor radon measurements by solid state nuclear track detectors (SSNTD), some improvements were implemented during 2009, including new film supports, modifications to the etching process and improvement of the measurements quality assurance.

During 2009, several interventions were carried out on the Radionuclide Particulate Station (RN53) at S. Miguel, Azores, including the substitution of some electronic components of the detection system and pump inverter. The testing phase was initiated at December and last for three weeks of continuous working. Due to a detector breakdown, the test was stopped and the detector was sent to Italy for repair. After return, the detector will be installed and a new testing phase will begin, aiming the certification of the station during 2010. 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. The technical services concern the evaluation of the radioactivity levels in public water supplies (Decree-Law nº306/2007) and mineral waters and indoor radon measurements. The group income of these technical services was about 35 000 €.

A great effort of the Group have been undertaken in order to submit the accreditation of three radioanalytical techniques to IPAC, which was carried out in October 2009. Some of the members Group elaborated the technical and management procedures following the ISO/IEC 17025 requirements and have also participated on the Technical and Management Working Groups.

Two researchers of the Group were involved on the working group to define the ICP-MS characteristics and have also participated as Jury membership of the tender to its acquisition.

Members of the Group were involved in several committees from EU (Group of Experts of Art. 35), IAEA, CTBT.

One of the tasks of the Group is the education and training of staff and young students. During this year two MSc theses and two DFA in "*Safety and Radiological Protection*" were concluded..

Research Team

Researchers

M. J. MADRUGA, Princ., Group Leader
F. P. CARVALHO, Princ.
M. J. REIS, Aux. (25%)
J. A. CORISCO, Aux.

Students

A. R. GOMES, FCT grant
H. FONSECA, FCT grant
J. MELO, FCT grant
E. ANDRADE, (MSc, until October 2009)

Technical Personnel

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

Collaborators

I. LOPES
M. M. MALTA

Radiological Environmental Monitoring Programmes

M.J. Madruga, F.P. Carvalho, M. Reis, 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. F. Pereira, A. Batista

Objectives

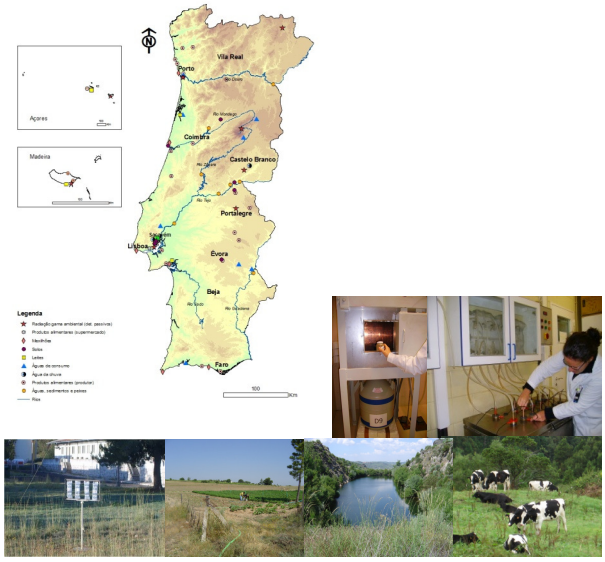
The Article 35 of the EURATOM Treaty stipulates that "*each Member State shall have the facilities necessary to carry out the continuous monitoring of the levels of radioactivity in the air, water and soil and to ensure the compliance with the Basic Safety Standards*". The Article 36 of the same Treaty 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.

Results

The monitoring programme at a national level concerns the radioactivity measurements of environmental and foodstuff samples collected along the country. The monitoring programme carried out for the ITN *campus* includes measurements of external radiation levels (gamma dose) and determination of radionuclide activity concentrations in relevant environmental samples (aerosols, rain water and soils) in order to check the operation conditions and discharge controls adequacy and to maintain a continuing record on environmental radionuclide levels related to the source. Monitoring of the regions around old uranium mining and milling sites was performed. Field missions were carried out in the counties of Guarda, Trancoso, Pinhel, Nelas, Mangualde and in the hydrographic basin of Mondego River, to collect water, soil, and vegetable samples for analysis in the laboratory. Radon measurements and aerosol samples were collected near the uranium mining waste dumps. Particular attention was paid to contamination of agriculture soil and irrigation water near uranium mining waste, and radionuclide soil-to-plant transfer. In mine pits that are now permanent ponds with aquatic fauna including fish, radionuclide accumulation by fish was investigated in order to assess the risk of radiation exposure to fish consumers. Radionuclide transfer to vegetation spontaneously growing on sludge from acid and radioactive mine water treatment was investigated as well.



During 2009 about 650 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 2200 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 dosemeters 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 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, J. Alves, J.A. Corisco, R. Trindade, N. Pinhão, J.M. Oliveira, A. Libânio, A. Mourato, G. Silva, L. Portugal, I. Lopes, L. Silva, J. Abrantes, L. Torres, M. Malta, A.R. Gomes, G. Carvalhal, H. Fonseca, J. Melo, M. Pereira, A. Batista. Programas de Monitorização Radiológica Ambiental (Ano 2008). *Internal Report* DPRSN, Série A, nº33/2009, ISBN 978-989-96542-0-4, Depósito Legal 194022/03, pp. 143.

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 given continuation 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 plant biomass.

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

Man-made, such as ^{137}Cs and $^{239+240}Pu$, and naturally-occurring radionuclides such as ^{210}Pb and ^{210}Po, are introduced in the ocean by atmospheric deposition and coastal discharges. 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 to biota and to the human population through ingestion of sea food. Monitoring of radionuclide levels 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. This was part of a Master Thesis (M. Malta). Atmospheric radionuclide depositions in the North East Atlantic were assessed through analysis of soil samples from Azores.

Project "CAPTAR"
F.P. Carvalho

Participation in the web based education project coordinated by the University of Aveiro and funded by the Calouste Gulbenkian Foundation. The project aims at producing a scientific periodical (Captar: ciência e ambiente para todos) available on line (http://captar.web.ua.pt/) for education and motivation of students and young researchers in environmental sciences. Two journal issues were released in 2009.

Radiocaesium Adsorption/Desorption on Geomaterials from "Raña" Deposits
M.J. Madruga, E. Andrade[1], I. Paiva, I. Bobos[1]

This study concerns the characterization of geomaterials from "Raña" deposits for radiocaesium adsorption and is part of a research project KADRWaste, funded by FCT[2] whose aim is to establishing methodologies for the characterization of medium and low activity radioactive waste repositories. It is very important to select geomaterials which can be used as effective barriers in radioactive waste disposal sites, in order to avoid migration of radionuclides in case of accident/incidents. The main objective of this study is to know the radiocesium (^{137}Cs) behavior in a specific geomaterial denominated "Raña" and to evaluate its potentialities as lining materials for radioactive waste repositories. This radionuclide is part of the radioactive waste inventory resulting from the application of radioactive materials in health, industry, teaching and research activities. Two geomaterial size fractions (<36µm and <63µm) were characterized in terms of pH, organic material content, cationic exchange capacity (CEC), adsorption capacity of specific adsorption sites ((*Frayed Edges Sites* - FES) and Radiocesium Interception Potential (RIP) of potassium ion. The characterization of these geomaterials is still at a very preliminary stage. Therefore, the results obtained up to now do not allow to concluding for the uses of these materials as protection barrier in radioactive waste repositories. More research studies concerning the adsorption/desorption behavior of radiocaesium in these materials will be developed.

[1] Faculty of Sciences, University of Porto

Accreditation of Radioanalytical Techniques
M.J. Madruga, I. Lopes, A. R. Gomes, J. Melo, J. A. Corisco

In order to achieve the accreditation of the radioanalytical techniques the elaboration, according to the ISO/IEC 17025 Standard, of the management and technical procedures to the alpha/beta measurements using proportional counter and Liquid Scintillation Counting (LSC) as well as to the tritium determination by LSC in waters has been performed. Same improvements were implemented on these methods, mainly concerning the quality assurance. The accreditation procedure for these three techniques was submitted to Instituto Português de Acreditação (IPAC) in October 2009. In the framework of the IAEA project (RER/0/031-Strengthening Sustainability of Nuclear Research and Development Institutes in the Modern Science and Technology Environment) the Group host the visit of five AIEA experts on QA/QC and accreditation procedures and a Group collaborator spend two weeks for training in tritium measurements in waters at CIEMAT (Spain).

Indoor Radon Measurements

M. Reis, H. Fonseca

During 2009 some improvements were implemented regarding the indoor radon measurements using solid state nuclear track detectors (SSNTD). New film supports were acquired and are now in use. The new supports are more users friendly and allow a better protection of the LR115 film, avoiding unexpected exposures and wrong handling of the detectors by the costumers. A new geometry for the film reading is now in use, which implies changes in the etching process. Some modifications to the usual procedures were also implemented in order to improve the quality assurance.

Efforts were made in order to implement in the near future the use of seasonal correction factors.

We receive a scientific visitor (1 week) from University of Extremadura, Spain, for training in radon measurements using SSNTD and for intercomparison of continuous radon monitors.

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 nº306/2007) the UPSR was requested by Water Suppliers to carry out the determinations of global alpha, global beta, Tritium, ^{238}U, ^{234}Th, ^{226}Ra and ^{210}Po 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 nº84/90). The radiological study included analyses of ^{226}Ra and global beta. Several enterprises often request this radiological study.

During 2009, a total of about 300 analyses were performed.

2. Indoor Radon

M. Reis, H. Fonseca

Following the National System of Building Energetic Certification for the Indoor Air Quality (Decree-Law 78/2006, 4th April) public and private enterprises request to GRA the measurements of indoor radon. Besides, since November 2003 a collaborative Protocol was established between UPSR-ITN and DECO to answer the associate's indoor radon requests.

In 2009, about 550 measurements were performed and around 800 requests are going on.

Measurement Laboratories

Mário João Capucho dos Reis

The Measurement Laboratories (LM) provides analytical services in the area of radioactive analysis 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 LM carries out Portugal's obligations under Article 35 of the EURATOM Treaty which requires member states to conduct national environmental radiological survey annually.
The LM is also involved in research work and provides analytical services to external clients in order to support industrial and commercial activities.
The techniques used are high resolution gamma-ray spectrometry; gross alpha/beta counting and beta counting of specific radionuclides 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.
The range of radioactivity measurements includes: analysis of radioisotopes in water to assist in the surveillance of ITN's research reactor, control of foodstuffs, export or import products and building materials, analysis of gross alpha/beta and tritium in drinking water (in collaboration with the GRA) and measurement of ^{3}H in biological samples for cancer research purposes (by request of Radiopharmaceutical Sciences Group of UCQR).

During 2009, the group was involved in several international intercomparison exercises, in collaboration with the GRA, and have also participated in a gamma spectrometry proficiency test organized by the National Physical Laboratory (UK).

In the beginning of 2009, the group has participated, in collaboration with other ITN groups and Universities, in the elaboration and submission of 4 research projects (one of them as project leader) for FCT funding. The group remains also involved in the ongoing *KADRWaste* project.

During this year further cooperation between the Measurement Laboratories (LM) and Dosimetry and Radiobiology Groups (GDR) was developed, regarding the simulation of HPGe detectors using Monte Carlo techniques and its application on efficiency calibration computation as well as self-attenuation and coincidence summing correction factors calculation.

Finally, the LM staff was also involved in the preparation of the accreditation process of the radioanalytical techniques, following the ISO/IEC 17025 standard.

Regarding the education and training, during 2009:

- Two group members have initiated a post-graduation training programme (DFA) on Radiological Protection and Safety, at the Technical University of Lisbon;
- One group member concluded the post-graduation studies (DFA) on Radiological Protection and Safety, at the Technical University of Lisbon.

Research Team

Researchers
M. REIS (75%), Aux.

Fellows and Collaborators
L. SILVA
J. ABRANTES
L. TORRES

Technical Personnel
J.M. OLIVEIRA (30%)
G. SILVA

Students
G. CARVALHAL

Using a Monte Carlo simulation method for geometry, matrix and coincidence summing effects correction

L. Silva, G. Carvalhal, M. Reis

Objectives

The Gamma Spectrometry Laboratory has to deal with samples of a wide variety of characteristics. Experimental calibration for all the matrix and geometry configurations of interest could become unpractical and extremely expensive. The computation of efficiency transfer factors for different geometries and correction factors for different types of matrices using Monte Carlo based simulation codes is an effective way to overcome this difficulty. The main objective of this work is the implementation of correction factors by using Monte Carlo simulation, in order to apply the method to several matrices, geometries and radionuclides of interest.

Results

In gamma spectrometry, specific conditions for efficiency calibration are: specific geometry, specific matrix and specific detection processes. When these specific conditions are not met for a measured sample, the result of that measurement will not be traceable. For assuring traceability, appropriate correction factors must be calculated. The matrix effects are especially significant for large sample volumes. Such geometries improve the detection sensitivity but introduce significant self attenuation effects, especially in the low energy range. Also, the phenomenon of true coincidence summing is no longer negligible, due to the common use of high volume detectors together with short distance measurements. There are also situations when the geometry configuration of the sample to be analyzed is different from the geometry configuration used for efficiency calibration. In this case, efficiency transfer factors should also be computed in order to correct for these geometrical differences.

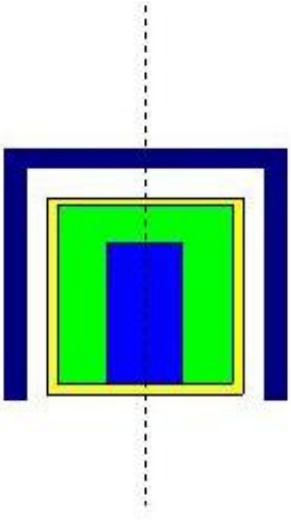
The work was initially focus on two detectors: a p-type coaxial detector with 40% relative efficiency (Canberra® model GC4019) and a n-type broad energy detector with 50% relative efficiency (Canberra® model BE5030). Experimental calibrations were made using traceable volume and point sources, and validation of the corrections was performed by using water and soil reference samples from previous intercomparison exercises.

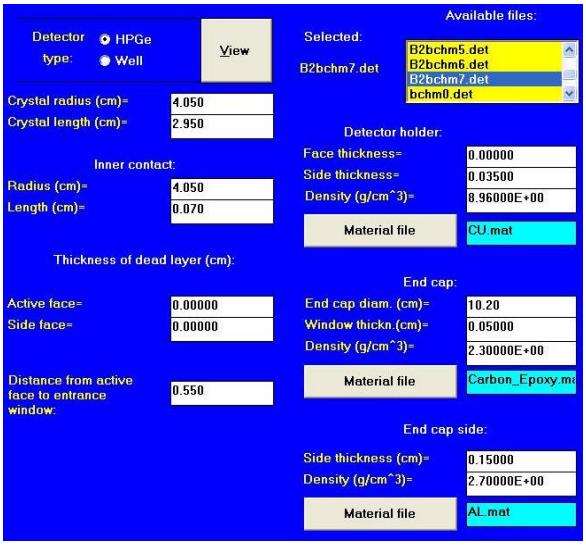
The computation of correction factors for coincidence summing (F_{COI}) and matrix effects (F_{MAT}) and the calculation of efficiency transfer factors (F_{TR}) for different geometries were performed by a Monte Carlo based simulation code.

It was found that corrections factors for geometry, matrix and coincidence summing effects in gamma spectrometry are necessary when specific calibration conditions are not met in sample measurements. These corrections are mandatory in order to maintain metrological traceability in gamma spectrometric measurements with close source to detector geometries, for different matrices and for different geometries. The implemented methodology complements experimental calibration, ensuring the traceability of the gamma spectrometry measurements.

Published Work

L. Silva, G. Carvalhal, M. Reis, Corrections for geometry, matrix and coincidence summing effects in gamma spectrometry: a requirement for traceability, *IAEA Technical Meeting on Quality Assurance for Nuclear Spectrometry Techniques,* Vienna, Austria, 12-16 October 2009.





Application of Monte Carlo Techniques to Gamma Spectrometry
G. Carvalhal, L. Silva, P. Nogueira, J. Bento, P. Teles, R. Luís, P. Vaz

During this year further cooperation was developed between the Measurement Laboratories (LM) and the Dosimetry and Radiobiology Group (GDR), regarding the application of Monte Carlo simulation techniques to computational efficiency calibration of HPGe detectors, computation of self-attenuation and coincidence summing correction factors and optimization of a whole body counter.

Accreditation of Radioanalytical Techniques
J. Abrantes, G. Carvalhal, M. Reis, L. Silva, G. Silva

During 2009 the group was involved in the preparation of the accreditation process according to ISO/IEC 17025 standard. In order to help with the process the group was visited by IAEA experts, under the framework of the IAEA Project RER/0/031 (Strengthening Sustainability of Nuclear Research and Development Institutes in the Modern Science and Technology Environment). One group member went for a training programme (IAEA financed fellowship) related to the subject of QA/QC practices in gamma spectrometry, at the Radioanalytical Reference Laboratory, Hungary.

Services

Analytical Services on Radioactivity Measurement and Liquid Ion Chromatography
J. Abrantes, G. Carvalhal, J. M. Oliveira, M. Reis, L. Silva, G. Silva, L. Torres

In 2009, around 2000 analysis have been performed (excluding analysis for calibration, quality control and intercomparison exercises). 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 about 16 kEuros.

Dosimetry and Radiobiology

Pedro Vaz and Berta Martins

During 2009, the reorganization, of the activities in the areas of Dosimetry and Radiobiology, was consolidated. The synergies of the competences held by the GDR researchers and technicians were further strengthened, in order to address in a more efficient way the multidisciplinary, cross-cutting leading-edge scientific and technical issues that characterize modern Dosimetry and Radiobiology.

The main components of activity of the GDR are Individual Dosimetry, Computational Dosimetry, Internal Dosimetry, Biological Dosimetry, Radiobiology and Radiological Safety Assessment of installations. Special emphasis was devoted during 2009 to the expansion of the activities in the area of Biological Dosimetry and Internal Dosimetry. The competences in several radiobiological and bio-dosimetric techniques were strengthened in order to improve the preparedness in radiological emergencies and accidents; the Whole Body Counter was made operational, in cooperation with experts from CIEMAT (Spain) and SCK/CEN (Belgium). The existing competence in Computational Dosimetry, (in Monte Carlo simulations) was deployed in support of modelling of radiological installations and radiation detectors.

Researchers and fellows from the GDR have collaborated in many activities, namely:

- Several R&D projects conducted by international consortia, in the E.U. 6th and 7th Framework Programmes or in collaboration with CERN,
- Submission of research projects to the Portuguese Foundation for the Science and Technology,
- Submission, by international consortia, of projects to the E.U. 7th Framework Programme,
- EURADOS.

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). GDR researchers participated in international activities aiming at defining the needs and assessing the capacity of response in the European Union, in a major radiological emergency situation.

The 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 and to the Portuguese Foundation for the Science and Technology (FCT). Collaborative links with hospitals and clinics were fostered. Several Masters thesis were accomplished under the supervision of GDR researchers.

The effects of low doses of ionizing radiation and associated topics are currently a priority in scientific research worldwide. The biological effects of radiation and the persisting uncertainties about the mechanisms of response of cells, tissues and biological systems in the range of low doses, the implications that major findings on the impact of the exposure to 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 are currently very hot scientific- and regulatory- related topics and issues. The ITN joined during 2009 the EU-platform MELODI (Multidisciplinary European LOw Dose Initiative") that will be defining the topics, a roadmap and a strategic research agenda for the low dose research in Europe for the coming years.

Concerning the technical services provided, the GDR continued to operate its individual dosimetry and monitoring services and to perform the safety assessment of radiological installations (cyclotrons, radiotherapy vaults and nuclear medicine services).

The Central Dose Registry (CDR) for occupational exposure continued to collect and store on a quarterly basis the dosimetric data from the seven monitoring services and companies operating in Portugal.

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, Masters and Ph.D. theses.

Researchers from the GDR acted as national representatives in Committees and Working Groups under the auspices of the EU, the IAEA and the OECD/NEA and assisted the Portuguese Government in the drafting of legislation and regulations.

Research Team

Researchers

P. VAZ, Princ.
M.B. MARTINS, Princ. (until Oct.)
M.A. NEVES, Princ.
J. G. ALVES, Aux.
O. MONTEIRO GIL, Aux.
A. D. OLIVEIRA, Aux.
P. TELES, Aux. (Contract)
M. GOULART, Aux. (Contract until March)

Technical and Admin. Personnel

T. ANTUNES
M. MARTINS
M. SARAIVA

Fellows and Collaborators

A.C. ANTUNES
A. BELCHIOR
J. BENTO
C. BORGES
C. CARRAPIÇO
R. F. LUIS
V. MARTINS
P. NOGUEIRA
M.F. PEREIRA
S. RANGEL
Y. ROMANETS
R. SARMENTO
D. RUIVO

Advances in research and in emergency preparedness

J. Alves, A. C. Antunes, A. Belchior, J. Bento, G. Carvalhal, R. Luís, M. B. Martins, V. Martins, O. Monteiro Gil, M. Neves, P. Nogueira, A. Oliveira, M.F. Pereira, Y. Romanets, L. Silva, P. Teles, P. Vaz, I. Balásházy[1], L. Peralta[2], P. Almeida[3]

The assessment of the risks associated with low dose or protracted exposures, is of utmost importance in the framework of medical applications of ionizing radiations, in environmental exposure and for aircrew and frequent flyers. Preparedness of response in the framework of radiological accidents, radiological emergencies, terrorist and malevolent acts is also of paramount importance. Bearing this in mind and taking into account that the biological effects induced by low radiation doses are not well understood, several activities and studies were undertaken aiming at exploring the existing synergies and competences in physical, computational, internal and biological dosimetry.

Assessment of the doses to the staff in fluoro-CT guided procedures was performed using whole body and extremity dosimeters (Figure 1). In this study the dose distribuition received by the medical doctor in this type of procedures was initiated.

Fig.1 Glove with extremity dosimeters for dose mapping of the hand.

In terms of internal contamination, the Whole Body Counter (WBC), unique equipment of its kind in the country, was reactivated. A dedicated phantom (BOMAB) was acquired, in order to perform standardised calibrations (Figure 2).

Fig.2 WBC and the BOMAB phantom

This equipment is of vital importance in the event of a radiological emergency, and for monitoring internal contamination of workers. Specific competence in biokinetic models used to estimate the effective committed internal dose was strengthened. Specialised software was acquired and developed.

Computational studies using Monte Carlo simulations were undertaken in order to gain further insight into the operation of HPGe detectors and to optimise the response of these detection systems (Figure 3).

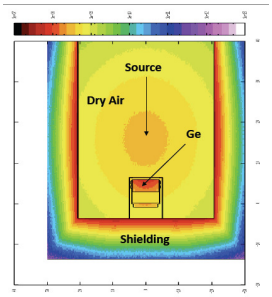


Fig.3 Dose distribution around a broad energy detector (BEGe) using the FLUKA Monte Carlo code.

These studies were complemented by biological dosimetry activities using implemented cytogenetic methodologies that allow us to quantify cellular damage induced by occupational radiation exposure and in radiological emergency situations, among others. Radiation biomarkers, such as the Micronuclei (Figure 4) and Chromossomal Aberrations assays allow studying genotoxic effects induced by radiation, at the chromosome level. These methodologies are already implemented both for adherent human cell lines and blood samples. Comet assay may also be considered an effect bioindicator, for recent exposure, allowing a more rapidly screening of the exposed population, since it is minor time consuming technique. Available protocols to quantify the cell survival include MTT and Clonogenic assay. Cytogenetic studies already performed include irradiation of human cell lines with ^{60}Co - LMRI, and ^{210}Po - in a device for cell irradiation gently sent to ITN by the KFKI[1] under collaboration between both institutions.

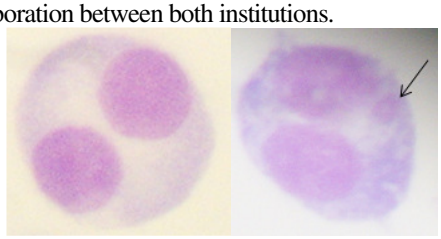


Fig.4 Micronuclei assay. a) binucleated cell b) binucleated cell with a Micronuclei (arrow).

Published, accepted or in press work

P. Nogueira, L. Silva, P. Teles, J. Bento and P. Vaz. Monte Carlo simulation of the full energy peak efficiency of a WBC. Accepted in *Applied Radiation and Isotopes* 68 (1), (2010) 184-189.

J. Bento, P. Teles, L. Silva, P. Nogueira, M. Neves and P. Vaz. Performance parameters of a Whole Body Counter. *Radiation Measurements*, in press.

P. Nogueira, L. Silva, P. Teles, E. Fernandes, A. D. Oliveira and P. Vaz. A Monte Carlo simulation of a whole body counter. *Int. Journal of Low Radiation*, 6 (4), (2009) 312-324

M. Neves, Target radiotherapy and radiobiology, *World Journal of Nuclear Medicine*, 8 (4), (2009) 227-228

[1] KFKI – Hungarian Academy of Sciences, Hungary.
[2] Departamento de Física, FC-UL.
[3] Instituto de Biofísica e Engenharia Biomédica, FC - UL.

Dose response curve for biological dosimetry

V. Martins, C. Antunes, O. Monteiro Gil

We are performing a dose response curve for biological dosimetry in case of low level radiation exposure. This is the first time that such study is undertaken for Portuguese individuals. With this purpose we have irradiated *in vitro* peripheral blood lymphocytes from healthy donors. The samples irradiation, with absorbed doses of 0.0; 0.25; 0.5; 0.75; 1.0; 2.0; 3.0Gy, was performed with a ^{60}Co source, locate at LMRI/ITN.

Donor's age range spans 20-60 years, which has been quantized in intervals of 10 years. Study groups were composed of two men and two women. A total of 200 metaphases were analysed, per pair donor-dose, by two independent scorers (100 each). An additional scorer was used for aberrant cells confirmation.

A set of 7000 metaphases with 46 chromosomes, using the chromosomal aberrations assay, has been studied so far (see Figure 1).

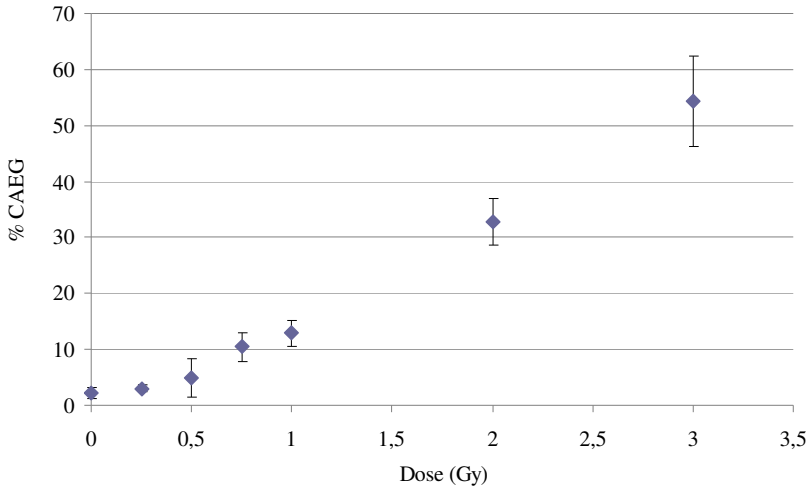


Fig.1 Clastogenic effects induced by ionizing radiation (^{60}Co). %CAEG - number of aberrant cells excluding gaps. Each point represents the average of 5 healthy donors (total of 7000 metaphases scored).

Comet assay implementation

A. Belchior, V. Martins, C. Antunes, O. Monteiro Gil

We have performed the implementation and validation of another cytogenetic technique the Comet assay in peripheral blood lymphocytes and in immortalized human cell lines (human lung cell – A549). The studies were done using ^{60}Co (LMRI/ITN) for peripheral blood lymphocytes irradiation.

The validation of this technique was also performed in human lung adherent cell line– A549 by using a cytotoxic agent, H_2O_2. Different concentrations were applied, 0, 100, 500 and 1000 mM in order to quantify the DNA damage induced by H_2O_2 (see Figure 1).

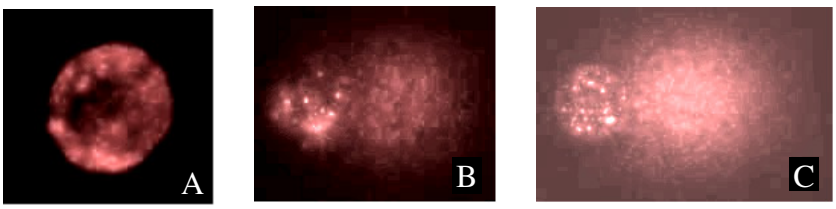


Fig.1 DNA damage induced by H_2O_2. (A) without H_2O_2 (B) 500 mM of H_2O_2 and (C) 1000 mM of H_2O_2

Radioprotective effects of manganese(III) porphyrins on the genotoxicity induced by low LET radiation (Co-60) in human lymphocytes

A.S. Fernandes[1], V. Martins, N.G Oliveira[1], O. Monteiro Gil

The aim of this on-going work is to study the influence of manganese(III) porphyrins with superoxide dismutase activity on the protection against the genotoxic effects induced by ionizing radiation (IR). For this purpose, the cytokinesis-blocked micronucleus assay was chosen to assess the level of IR-induced DNA damage in peripheral blood human lymphocytes from 8 healthy non-smoking donors (*in vitro* experiments). The absorbed dose of IR selected for these studies was 1 Gy.

[1] CBT-iMed.UL /FFUL

Biological effects induced by alpha radiation - Micronuclei assay

A. Belchior, I. Balásházy[1], L. Peralta[2], P. Almeida[3], P. Vaz

A new experimental design for α-particle irradiation of cells in vitro based on ^{210}Po radioactive source was built by I. Szabó (Fig. 1) and gently send to UPSR/ITN, under collaboration with the Hungarian Atomic Energy Research Institute (KFKI). Before the utilization of the α–particle irradiator, experimental measurements were performed with a Si(Li) surface barrier detector to estimate the energy and LET spectra at the cell monolayer (Fig. 2).

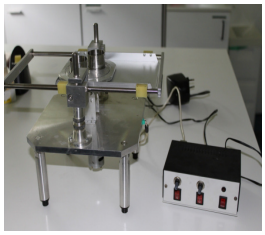
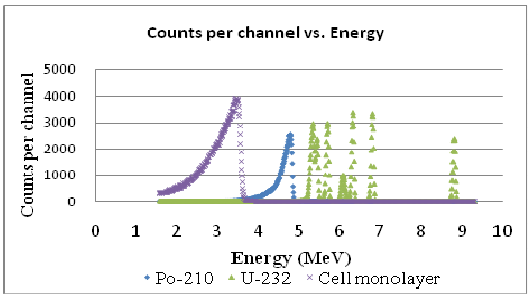
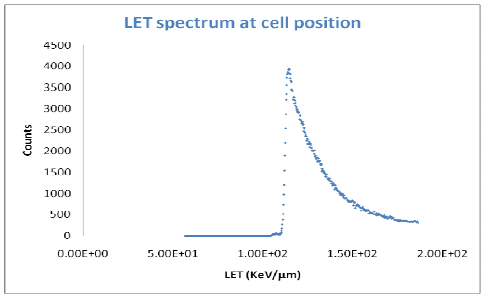


Fig.1 α-irradiator





To quantify the genetic lesion induced by alpha radiation (^{201}Po and ^{241}Am) in immortalized human cell line (human lung cell – A549) we have implemented the cytogenetic technique - cytokinesis-blocked micronucleus assay. This technique predicts the genetic lesion by the scoring of the number of micronuclei in binucleated cells. The first results pointed out an increase of DNA damage with dose.

[1]KFKI Hungary; [2]IBEB-Fac.Ciências, UL, [3] Dep. Fisica - Fac.Ciências, UL

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

J.G. Alves, P. Ambrosi[1], D. Bartlett[2], L. Currivan[3], J.W. van Dijk[4], E. Fantuzzi[5], V. Kamenopoulou[6]

The aim of this project was 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, which ended in April 2009. This work was also developed in the framework of the activities of Eurados (European Radiation Dosimetry Group) Working Group 2 (WG2) on *Harmonization of Individual Monitoring in Europe*. Following the inputs and comments received from the various stakeholders, namely, Eurados WG2 members, the contact persons from the Extended Group of European Countries (EGEC), European and other international organizations such as IAEA, IEC, ISO, ICRU, ICRP, ESOREX, EUROMET and EAN a final report was prepared and delivered to the European Commission. The document was presented to the Article 31 Group of Experts for discussion and approval at their meeting of 09-11 June 2009. The Article 31 Group of Experts endorsed the document and recommended it for publication by the Commission.

[1] PTB, Germany; [2] UK.; [3] RPII, Ireland; [4] Netherlands; [5] ENEA, Italy; [6] GAEC, Greece.

Dose assessment in medical applications – staff and patient dosimetry

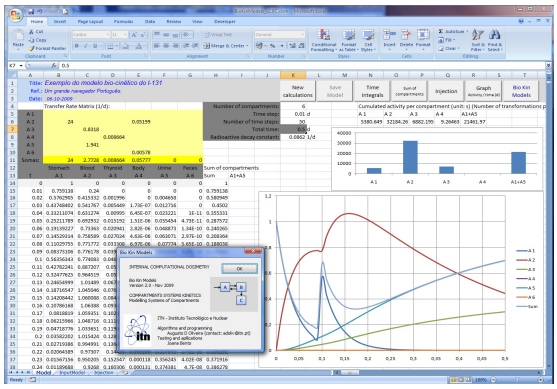
J.G. Alves, M.F. Pereira, A. Pascoal[1], J.M. Santos[2], S. Sarmento[2], F. Carrasco[2], R. Correia[2,3].

The main objective of this line of activity is to carry out staff and patient dosimetry studies in various medical applications, such as mammography, interventional radiology procedures and radiotherapy, under the framework of collaborations with *Universidade Católica Portuguesa* and *Instituto Português de Oncologia do Porto*. The results obtained allowed the preparation and presentation of MSc thesis by M.F. Pereira at Univ. Lisboa (staff dose measurements in fluoro-CT guided procedures) and R. Correia at Univ. Porto (TLD measurements in radiotherapy treatments of tracheostomized patients). Three research projects were also prepared with ITN as partner and submitted to FCT on February and December 2009 calls. Under the framework of the collaboration with UCP, project PTDC_SAU-BEB_100745/2008 entitled *Digital technologies in Mammography: optimization using Monte-Carlo simulation methods*, was submitted and considered eligible for funding. Based on the collaboration with IPO-Porto, projects PTDC_SAU-ESA_105178/2008 (Feb 2009 call) and PTDC_SAU-ENB_115792/2009 (Dec 2009 call), respectively entitled *Evaluation of critical doses for the optimization of radiation protection in fluoro-CT guided interventional procedures*, and *Dose distribution and Monte Carlo simulation studies in fluoro-CT*, were both submitted to FCT. The former was not approved for funding and the latter is presently under evaluation.

[1] Univ Católica Portuguesa, Fac. de Engenharia, [2] Inst. Português de Oncologia do Porto, Grupo de Física Médica, [3] U. Porto

BioKinModels – Compartment Systems Kinetics

A.D. Oliveira, J. Bento



Bio-kinetic models are a major issue in internal dosimetry in order to determine radiation doses received by individuals from radionuclides which enter the human body. A new computational tool which can be used to solve any first-order kinetics models of compartments is in development, presently at version 2.0. One of the advantages of this computational tool is that additionally to the solution of a given compartment model, it allows detailed analysis of the model. In a very intuitive an easy way one can change the parameters of the model such as the value of the transfer rate constants; add or remove one or several compartment and study their influence in the whole model. One can also change the pathway of the radionuclide between compartments which allows a deeper understanding of a given model. The tool was made with the perspective for application in internal dosimetry however it can be applied to any discipline which uses compartment models such as radioecology, for example.

Internal Dosimetry activities –Whole Body Counter operation, biokinetic model studies, and other activities.

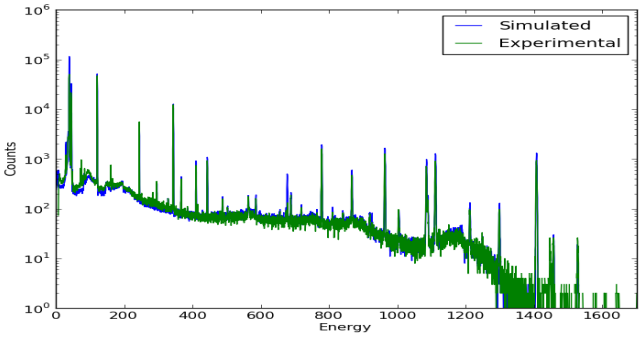
P. Teles, J. Bento, M. Neves, P. Vaz, A. Oliveira

Significant progress has been made throughout 2009 in implementing Internal Dosimetry activities at the Radiological Protection and Safety Unit of ITN. The Whole Body Counter (WBC) at ITN has been set-up and calibrated, and its performance parameters are routinely assessed following a Quality Assurance programme. As such, the WBC is currently operational and prepared to respond to radiological emergencies in Portugal. This work is already published in an international peer-reviewed journal It is also prepared for the routine monitoring of personnel, we intend to implement within the Portuguese workers, in the Medical field nationwide. A Workshop is currently being organized in order to debate these issues as well as ITN's role as a key-player in this project. Other on-going activities, started during 2009 include (i) Monte-Carlo simulations of the WBC, which can be used in several applications (ii) Effective dose estimation using biokinetic models – several studies using these models were reported at national meetings (iii) acquisition of new biokinetic model related software – IDEA system, MONDAL 3 (iv) acquisition of new equipment – Bottle Manikin Absorber Phantom (BOMAB, Figure1), the standard phantom in WBC calibrations. Finally, our work also included the participation in several workshops in international institutions (CIEMAT, SCK-CEN, IRSN) in which the methodologies and techniques used at ITN were debated, in order to optimize and standardize them. Moreover, bilateral collaborations were established with the aforementioned institutions, as well as collaborations within the framework of EURADOS, this included the hosting and organization of the Workgroup 7 (Internal Dosimetry) of EURADOS by the ITN.

Computational Dosimetry

P. Vaz, P. Teles, P. Nogueira, J. Bento, A. Belchior, R. Luís, Y. Romanets, R. Sarmento, L. Silva, G. Carvalhal, M. Reis

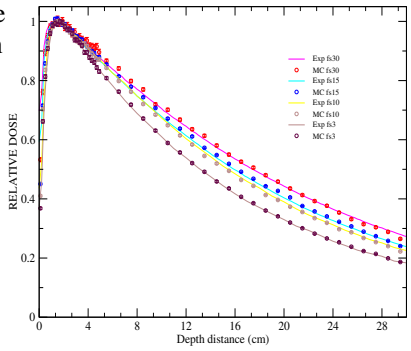
The existing competence in Monte Carlo simulations was deployed and made available to perform dosimetry and radiation shielding studies of radiological installations and to address modelling issues of radiation detectors. Of special relevance was the development of a transversal activity involving the Measurement Laboratory (LM) and the Dosimetry and Radiobiology Group (GDR), in order to gain further insight in the response of HPGe detectors (experimental and simulated spectra are shown in the picture), namely in the efficiency calibration, the self-absorption and coincidence summing corrections, among others. Of these activities resulted 3 articles accepted for publication in international peer reviewed journals. One CERN-ITN report was issued on the dosimetry and radiation shielding calculations of a multi-megaWatt target in the framework of the EURISOL project. Computation of fluence to dose conversion coefficients of the human eye lens were initiated in cooperation with the Helmholtz Zentrum (München). Finally,activities within the EURADOS Working Group on Computational Dosimetry were also undertaken, which included the study and application of voxel phantoms in the "in vivo" detection of gamma-particles in human lungs.



Use of Monte Carlo simulations to assess contralateral breast doses in breast cancer treatments

C. Borges [1,2,3], N. Teixeira [2,4], P. Vaz

The first main goal of this work is to present the validation of Monte Carlo simulations of photon beams (6MV and 15MV) of an electron linear accelerator that will be used in a lengthy and complex study to investigate different breast irradiation techniques and their influence on contralateral breast doses. The BEAMnrc® code was used to simulate a Trilogy®, Varian® accelerator head. A good agreement, in lateral and depth dose profiles, between simulated and measured data (in a water phantom) was obtained by manipulating the energy and the radius of the initial electron beam.



[1]Medicalconsult, SA, Portugal,
[2]Fac. of Medical Sciences Univ. Nova de Lisboa,
[3] Radiological Protection and Safety Unit,
[4]Escola Superior de Tecnologia da Saúde de Lisboa, Portugal.

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. Pires[1], 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. During 2009, the Portuguese team, actively participated in the following domains: i)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"). The Deliverable 1.54 entitled "Evaluation of radiation damage and circuit activation", of the responsible of ITN was issued, containing dose and neutron flux distributions and radiation shielding calculations, and the assessment of the radiation damage of the structural components. Participation on the studies of the reliability of the accelerator system were also performed. ii)DM2 – **ECATS** – *"Experiment on the Coupling of an Accelerator, a spallation Target and a Sub-critical blanket",* participating in 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 on neutronics studies and assessment of reactivity variations due to the insertion of control rods was issued.

[1] Fac. de Engenharia/Univ. Católica Portuguesa

Participation of ITN in the n-TOF-Ph2 experiment (PS213) at CERN

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

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/cm^2/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 2009, the ITN team members in cooperation with researchers from CEA/Saclay and INFN/Bari, participated in: the analysis of the ^{233}U neutron capture data sets, the analysis of the ^{236}U neutron induced fission data sets, and the data taking campaigns at CERN. The data analysis work is part of two on-going Ph.D. thesis. The ITN participation was undertaken in the framework of a project funded by the Portuguese Foundation for the Science and Technology (FCT).

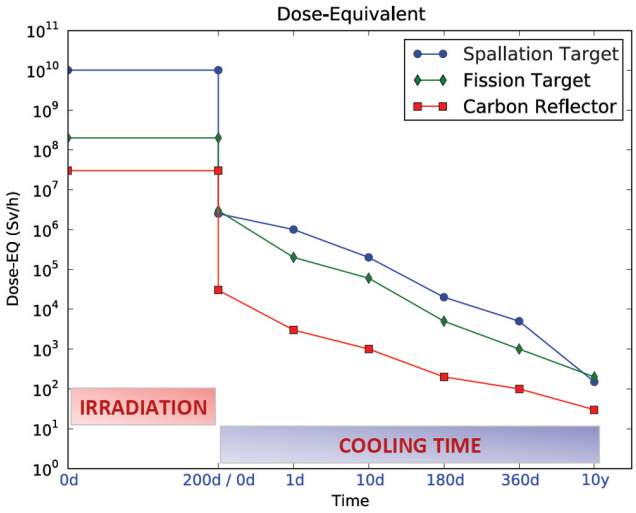
[1]FCT Ph.D. student, [2]- DF/ IST[3]–C. de Instrumentação / U. Coimbra

ENETRAP-II: European Network for Education and Training in Radiation Protection (Part-II)
P. Vaz

The project ENETRAP-II (Grant agreement number 232620) is a Coordination Action of the European Union in the 7th Framework Programme, in the context of the development of the Euratom Fission Training Schemes (EFTS) in all areas of Nuclear Fission and Radiation Protection. ENETRAP-II aims at the development and implementation of a high-quality European standard for initial education and continuous professional development fpor Radiation Protection Experts (RPEs) and Radiation Protection Officers (RPOs). The projects aims at developing a methodology for mutual recognition and setting up "reference" training schemes as an instrument to facilitate this mutual recognition, within the relevant regulatory framework. ITN participates in the work packages: WP 3 "Define requirements for RPO competencies and establish European guidance for RPO training", WP 4 "Establish the reference standards for RPE training", WP 5 "Develop and apply mechanisms for the evaluation of training material, events and providers", WP 8, "Organise pilot sessions, test proposed methodologies and monitor the training scheme effectiveness", and WP 10 "Collaboration for building new innovative generations of specialists in radiation protection"

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. 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 has participated during 2009, in the activities of the working groups, WP2 ("Multi-MW Target Station"), WP5 ("Safety and Radioprotection").



During 2009, the ITN team has accomplished, with the CERN team, detailed 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. A CERN-ITN report entitled *"EURISOL Multi-MW Target - MAFF configuration - Radiological Protection, Radiation Safety and Shielding Aspects"*, was issued detailing the main findings of the Monte Carlo simulations. The ITN participation was undertaken in the framework of one projects funded by the Portuguese Foundation for the Science and Technology (FCT).

Central Design Team (CDT) for a Fast-Spectrum Transmutation Experimental Facility CDT
P. Vaz, P. Teles, Y. Romanets

The Project CDT (Central Design Team) is a European Union co-financed Collaborative Project in the 7th Framework Program EURATOM (Grant agreement nº: *FP7-232527)*. The project aims at i) performing the advanced design of a fast spectrum transmutation experimental facility (FASTEF), able to demonstrate efficient transmutation and associated technology through a system working in subcritical mode (ADS) and/or critical mode and ii) to demonstrate the ADS technology and the efficient transmutation of high level waste; to operate as a flexible irradiation facility; to contribute to the demonstration of the Lead Fast Reactor technology without jeopardising the above objectives. The ITN team participates in the Work Package 2 entitled *"Design of the Fast Spectrum Transmutation Experimental Facility (FASTEF) in sub-critical & critical mode"* and lead the design of the in-vessel storage facility.

SERVICES

Individual Monitoring Service: individual and environmental monitoring

M. Martins, M.F. Pereira, M. Saraiva, S. Rangel, V. Batel[1], A. Calado[2], 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. In 2009, nearly 3,000 workers were monitored on a monthly basis using a whole body dosemeter Harshaw 8814 TL card and holder containing two LiF:Mg,Ti (TLD-100) elements for the evaluation of $H_p(10)$ and $H_p(0.07)$. Tests to the extremity dosemeter of the EXT-RAD type containing LiF:Mg,Cu,P (TLD-100H) included the participation in the 2009 Eurados Intercomparison exercise. An important component of the activity developed in 2009 was dedicated to the accreditation process of the IMS according to the EN ISO/IEC 17025 standard, preparing the necessary technical and management procedures. The application for accreditation was submitted to IPAC-*Instituto Português para a Acreditação* last October.
Environmental monitoring is performed for the National Radiological Environmental Monitoring programme carrying out quarterly measurements of the ambient dose equivalent $H^*(10)$ in nine sites spread over the country and in four sites at ITN *campus* with increased frequency. In 2009 a collaboration with CIEMAT-*Centro de Investigaciones Energéticas Medioambientales y Tecnológicas* (Madrid, Spain) was established in other to perform regular environmental dose measurements at both ITN and CIEMAT. Education and training related activities allowed the preparation and presentation of MSc thesis (M.F. Pereira, A. Calado and V. Batel).

[1] *Hospital S. João, Porto;* [2] *IST*

Central Dose Registry: Collection and Analysis of Occupational Dose data

M.B. Martins, J.G. Alves, T. Antunes

Decree-Laws 167/2002, 167/2002 and 222/2008 entrusts to ITN tasks relative to the creation and maintenance of the Central Dose Registry (CDR) for occupational exposure. The occupational exposure data of the workers monitored in Portugal in the period 1957-2009 are stored at the CDR and consist of 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. The monitoring services and companies operating in Portugal transfer data to the CDR on a quarterly basis. The analysis of the occupational dose data stored at the CDR is also an aim of this project, particularly in the case of activities associated to high dose values. The annual whole-body doses evaluated in the period 2000–2008 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, annual collective doses, as well as the total average and total collective doses were determined and will be presented on a full report that is currently being prepared.

Risk and Safety Assessment

A.D. Oliveira, T. Antunes, A. Baptista, R. Trindade, P. Vaz

Radiation safety assessments of complex radiological facilities had been carried out together with the Radioprotection and Radioactive Waste group. These services are running accordingly with international recommendations NCRP, IAEA, DIN, etc. as well as national legislation if available, resulting in expert level reports. Regarding the implementation of the safety culture we started a new approach by introducing the "Document for the Safety Culture". The income of this activity was about 35000.00 Euros. Participation in IAEA committee RASSC is an ongoing activity concerned with the IAEA safety standards which have straightforward implications in this activity.

Radioprotection and Radioactive Waste

Romão Trindade

The Radioprotection and Radioactive Waste Group (GRRR) is involved in many diversified activities ranging from R&D to services to the community and international representations by legal demand. In terms of R&D, GRRR has pursued its activities in the following funded organizations: FCT: KADRWASTE Project -ITN/UPSR/Lisbon, Porto and Évora Universities; FP7/Euratom-Fission: Integrated Project ACSPET- ITN-UCQR-UPSR; and Coordination Action PETRUS II- ITN-UPSR); IAEA: International project GEOSAF-ITN-UPSR/IAEA/NEA/EC.
Still in terms of R&D, the Group has participated in the elaboration of new candidatures to research projects that were presented to FCT in 2009.
Concerning Education & Training, two Master Degrees were completed during 2009, one in Microbiology of Soils with the collaboration of U. Aveiro (Dept. of Biology) and GDR/UPSR and the other in Applied Geology to Clays, with the collaboration of Sciences Faculty of Porto (Dpt. Geology) and the GRA/UPSR. A PhD degree in the field of radioactive waste management in collaboration with Sciences Faculty of Lisbon (Dpt. Geology) is ongoing.
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" at IST, Lisbon (Dpt. Physics). 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 national and international committees, working groups and task forces related to radwaste management, transport of radioactive materials, radiological protection and monitoring, decommissioning of radioactive and nuclear facilities, surveillance of contaminated scrap metal and radiological emergencies.

During 2009, ITN/UPSR/GRRR started radwaste data submission to the IAEA' NEWMDB Database. Also GRRR' members have participated in several informal meetings with CIPRSN, to analyse and discuss specific Portuguese legislation aspects in the broad area of radiological protection

Considering the activities related to legal obligations such as licensing of sealed sources for medical, industrial, teaching and research applications the Group has issued 304 licensing requested for analysis and authorization during 2009.

Also during last year and still considering legal obligations, 158 requests for collecting and storing radioactive waste were received and processed. Related to this subject, GRRR has sent to ITN/CD information about the situation in the storage site at ITN (PAIRR), resulting from lack of space and personnel. Despite the comprehension shown by the Authority, the reply received has not been sound enough to allow ITN/CD to take measures in order to solve what can become a serious problem in a very short time. However, both ITN/CD and GRRR have been pursuing activities (R&D) similar to what other Countries have been doing to foreseen a possible future solution.

Detection of radioactive substances in scrap metal is still in the increase as happening in other EU MS and only this year, 10 events were reported to ITN and monitoring by GRRR. Radiological protection and safety verifications of facilities were carried out by GRRR at 4 medical establishments and 4 industrial facilities. Radiological surveillance was carried out by GRRR during the stay of 3 military nuclear vessels at the Lisbon Harbour. The Monitoring Programme of the radioactive liquid discharges from public and private nuclear medicine facilities into the public sewage of Lisbon as well as the monitoring of the four ETAR'S (waste water treatment facilities) was continued in 2009, in collaboration with Lisbon Council Borough.

ITN's radioactive wastes discharges compliance with Artº 35º of Euratom Treaty recommendations was pursued in 2009 with the renewal and improvement of the new ITN's Treatment Station, the ECoDELiR. This has been another step into the direction of assuring a more efficiently controlled released into the outside sewer. The *Campus* environmental gamma radiation dose has continued to be assessed through the gamma monitoring network, GAMMANET and the data reported in the framework of the Euratom Treaty.

Setup of the Radiological Protection Program (PPR) for UPSR (approved by Directive Board of ITN) was another action that deeply involved GRRR in 2009.

Also in 2009, GRRR was involved in the specifications file elaboration to acquire an ICP-MS equipment and in the jury of the proposals appreciation.

Research Team

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

Technical Personnel
L.M. PORTUGAL, graduated technician
J. VENÂNCIO

Collaborators
P. DUARTE
A. BAPTISTA

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. Abel[1], A. Mateus[1], I. Bobos[2], I. Paiva, R. Trindade, P. Duarte, M. Reis, M. J Madruga, M. F. Araújo, J. Mirão[3] et al

This project (PTDC/CTE-GEX/82678/2006) has pursed its objectives in 2009 with the radiometric, chemical and mineralogical characterization of the two previous defined scenarios. The radiometric surveys consisted in several linear profiles (transects) with distinct lengths and waypoints spacing about 50m, completed with scatter waypoints to account for non-accessible areas. Radiometric data were obtained from *in-situ* gamma spectrometry with NaI(Tl) 3"x 3" e 5"x 5" probes (Target systemelectronic gmbh), a multichannel (MCA) and palmtop for data registration. In each point, detectors were calibrated with a certified ^{137}Cs sealed source and placed 1 meter above the soil with a special apparatus. After stabilisation, and at each waypoint ten values in "count rate" mode (cps) were registered. The geographic coordinates (WGS84 system) of the waypoints, with ca. 4m uncertainty, were obtained with a portable handled GPS.

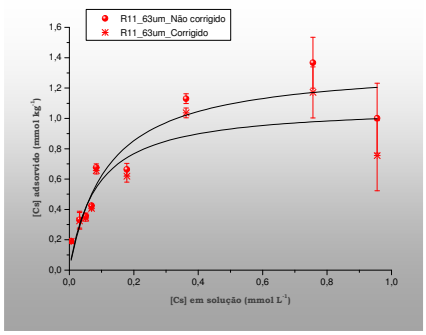
Statistical treatment of the data defined the sampling points for soils (vertical profiles in three different levels) rocks and surface vegetation. Samples were identified and taken out to the lab for pH and total organic carbon, determination, radiometric and chemical characterization of the total fraction and fraction sizes < 63 and < 36 micra. Radiological characterization of soils samples' different fractions were performed with HpGe planar detectors (LEM/LM/UPRS) and with NaI(Tl) planar detectors (GRRR/UPSR). Soil samples (<63 and <36 micra) were also analysed by ED-XRD, FTIR (FCUL and FCUP) and FRX (UCQR/ITN). Samples of surface and underground waters were also collected in different seasons for chemical and radiological characterization. The GIS software (ESRI® ArcMap™ 9.2) was used to construct the predictive maps characterising the spatial variability of the gamma radiation data, once the statistic parameter coefficient of variability, CV, can be used to verify the homogeneity and confidence of the measurements at each point). The spatial analysis of the raw data was carried out by applying the ordinary kriging as geostatistical method. To study the role of the different geologic formations on gamma radiation data, the Kolmogorov-Sminrnov test, with $\alpha = 0.05$ was used to test fitness of data from the two scenarios studied to normality. Also last year, specific rock fragments of selected soils were used to make fine slices for micro-probe analysis to access the presence of clay minerals, in special serpentine and inter-stratified minerals and resulting data was analysed by FCUL. Eight Teflon continuous flux reactors for batch mode experiments were constructed at ITN workshop according to a FCUL model to be used at ITN, FCUL and FCUP for adsorption/desorption studies of radioactive and non-radioactive elements in solutions containing clay minerals.

Included in the KADRWaste was also made a visit to El Cabril by Project participants from ITN, FCUL and FCUP.

Two Master Thesis within the framework of KADRWASTE were submitted and finished in 2009:

E.Andrade, *"Characterization of Geomaterials from raña Deposits for Radiocesium Retention"* (GRA/UPSR/ITN, GRRR/UPSR/ITN and FCUP).

S. Fernandes, *"Bacterial communities in soils with ability to retain radionuclides"*, I. Paiva (GRRR/UPSR/ITN) and A. Cunha (U.Aveiro, Dpt. Biology).



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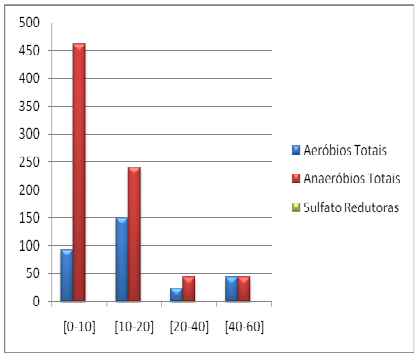


MNP technique

[1](FFC/Geology/Creminer/FC/UL)
[2](ADFC/Geology/FC/UP)
[3](U.Évora)

ACSEPT-Actinide reCycling by SEParation and Transmutation (7th Programme EURATOM- FP7-Fission 2007)

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

Related to ACSEPT Project were organized in 2009 several Scientific & technical domain review meetings. The start of ACSEPT provided early interesting results, and first results indicate optimization of GANEX and 1c-SANEX as well as the need to accelerate production of TOGDA ligands. ITN has already presented 3 HYBAR's (Half Yearly Beneficiary Activity Report) in Domain 1, WP1.2, D1.2.1, Design, Synthesis and Assessment of New Ligands linked to the Selection of an Efficient Extraction System for An (III) Group Separation and a presentation on the "Applications of the FT-ICR/MS Technique to ACSEPT Ligands Characterization". ITN experimental achievements, a collaboration between UCQR and UPSR, were exclusively carried out at UCQR facilities, using a Finnigan FT/MS 2001-DT FT-ICR mass spectrometer. The main experimental achievements were: Setup of the experimental methodology to carry out studies on gas-phase reactions of Ln (III) and An(III) with ligands provided by ACSEPT partners (CEA and CIEMAT) and using a Finnigan FT/MS 2001-DT FT-ICR mass spectrometer. Tests started with the ligand Me-BTBP from CE. Gas-phase association of the ligand with Gd(III) and Cm(III) as MCl_2^+ ions were performed. The formation of the MCl_2^+ ions from the reactions of M^+ or MO^+ with CH_2Cl_2 was studied in detail. The kinetics of the M^+ and MO^+ reactions with CH_2Cl_2 were studied and the reaction efficiencies determined. Preliminary studies with the Me-BTBP and TEMA ligands (CEA) in liquid phase, to study the competitive complexation with Pr, Nd and Sm were carried out using a Bruker HCT ESI-QIT mass spectrometer.

GEOSAF- International Intercomparison and Harmonization Project On Demonstrating the Safety of Geological Disposal

I.Paiva, P.Vaz, R.Trindade et al.[1]

This intercomparison and harmonization project on the safety of radioactive waste management (GEOSAF) carried out in support of safety demonstration for radioactive waste management facilities and activities have pursued its objectives in 2009. It was agreed to structure the project into two working groups, WG1 dealing primarily with safety demonstration methodology and WG2, focusing on the regulatory process.. Based on the critical review of previous studies on the subject, detailed questionnaires for both WG' s were developed during the meetings in Vienna, revised, sent to the MS and completed during 2009. The aim was to collect the relevant information from the GEOSAF participating MS to be used to start identifying possible issues for harmonization. Portugal, as a member of WG1, participated actively in the production of the respective questionnaire, by systematically reviewing the above mentioned documents, suggesting possible questions and subjects to be considered and by answering in relation with the National situation. Portugal also provided feed back to the Coordinator of WG1 on the answers provided by other MS as requested. Answers to both WG's questionnaires were synthesized by the SC and roadmap established has been revised in the last 2009 meeting in Vienna. For WG1 (Portugal), the focus of questionnaire should be kept on the technical issues that are expected to be reviewed by regulatory body at each phase of the safety case.

[1]IAEA MS, NEA/OCDE expert, EC expert

PETRUS II—Towards an European training market and professional qualification in Geological Disposal

I.Paiva, P.Vaz, R.Trindade et al.[1]

PETRUS II, an EC Coordination and Support Action Project on E&T has already started in January 2009 but the final contract was only signed in the last few days of October due to changes imposed by Brussels. The aim of the PETRUS II project is to enable present and future professionals on radioactive waste management in Europe, whatever their initial disciplinary background, to follow a training program on geological disposal which would be widely recognized across Europe. PETRUS consortium composed of academia, training centres, nuclear waste management agencies and research centres will co-operate through a suitable organisational structure for co-ordinating its activities and deliveries since the conception of the training programmes by taking into account both training providers and end-users point of view to the development of a framework for the mutual recognition and accreditation of the training programmes and the settlement of a plan for assuring the update and long-term sustainability of the programmes. So, main achievements of PETRUS II in 2009 were: changes in the structural form to comply in terms of FP7 guidelines, the writing of the terms of reference for the End-Users Advisory Group, the setup of the link to ENEN, the inclusion of other partners, the production of specific questionnaires according to partners' different characteristics, the fulfillment and analysis of the partner's replies, the presentation of a poster and a paper to the ETRAP Conference in Lisbon, Portugal, entitled: "Education and Training in Radiological Protection and Safety in Portugal: Collaboration between a University (IST) and a Research Centre (ITN)" and, finally, the inclusion of the Project in the First Implementing Geological Disposal Technology Platform (IGD-TP), launched in November 2009.

[1]Partners: INPL, CU, TUC, MA, POSIVA, ANDRA, ARAO, RWRA, ITC, REESN, GRS, NDA

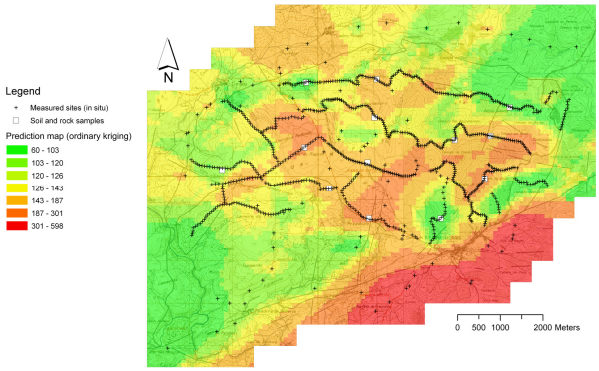
Characterization of Suitable Areas for a Long-Term Radioactive Waste Repository Facility in Portugal

P. Duarte, I. Paiva, A. Mateus[1], R. Trindade

The work in progress is part of a PhD thesis being carried out in collaboration with Department of Geology/FCUL. Statistical treatment of the data 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 laboratory for ongoing analysis by gamma spectrometry, ED –XRD and FT-IR. Samples of soils, rocks, clays and waters are still being analyzed.

The table gives a possible justification for gamma radiation and the in the map are the measures sites and the places where soils and rocks sample were taken.

Possible justification for gamma radiations abrupt variations	%
Geological boundary, fault or thrust fault	17
Geological boundary, fault or thrust fault + CV>10.8%	12
Watercourses crossing	12
Watercourses crossing + CV>10.8%	4
CV>10.8%	21
Without justification for now	35



[1]Dep. Geologia, FCUL

Services

1. Radioactive waste management

During 2009 about 158 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 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 nº 38/2007 and Decree-Law nº 165/2002, 304 sealed sources licensing were issued: national territory introduction licences (110), transfer licences (28), transport licences (44) and ownership licences (122). 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 35º and 36º of the Euratom Treaty.

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 35º and 36º of Euratom Treaty and to the Radioactive Substances Committee of OSPAR Convention. During 2009 the work to repair and to improve ECoDELiR was pursued.

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

In 2009 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. 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 2009. 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.

7. Nuclear vessels radiological monitoring

In 2009, three 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.

8. Radioactivity in scrap metal

In 2009, and as result of radiological surveys requested by the smelting industry, ten 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.

9. Radiological protection and safety verifications

During 2009, GRRR has carry out four verifications concerning radiological protection and safety at medical facilities in collaboration with GDR/UPSR and four at industrial facilities.