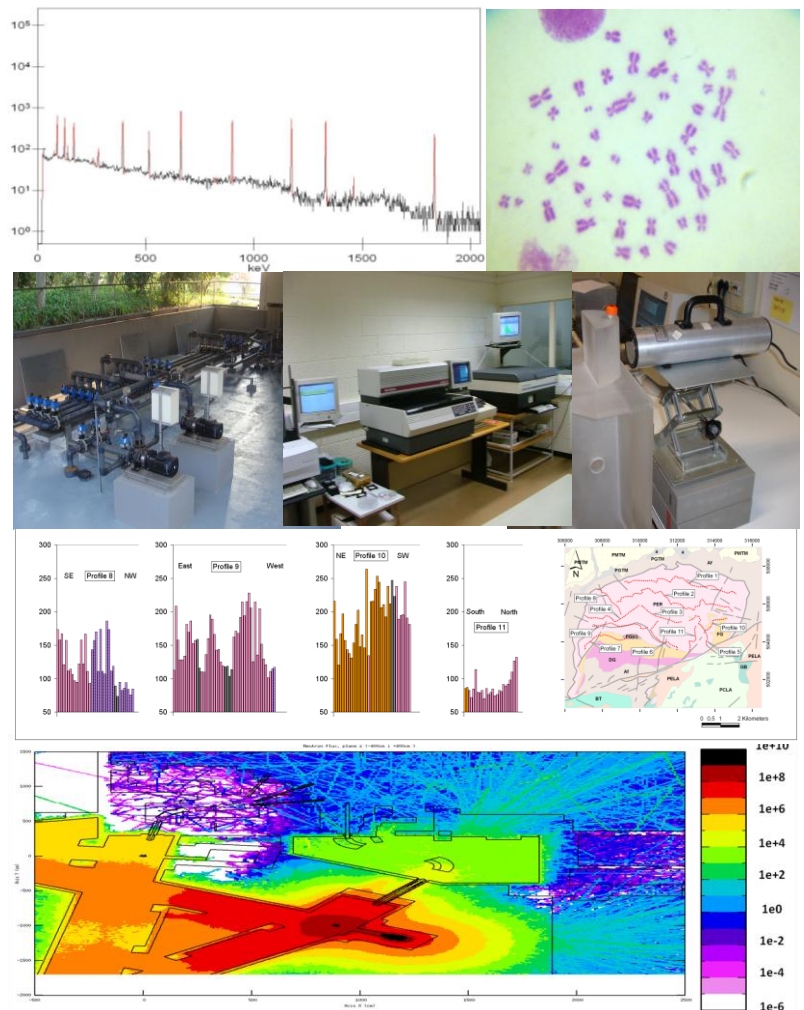


Radiological Protection and Safety Unit



Radiological Protection and Safety Unit

Pedro Vaz

During the first three quarters of 2010 a major effort was devoted to the final steps of the preparation for the accreditation by the Portuguese Institute of Accreditation (IPAC) of several radioanalytical, dosimetric and metrology techniques. The financial situation of ITN negatively impacted the efforts to accomplish the accreditation in 2010. The accreditation audits will take place during 2011.

The effort towards the installation of the ICP-MS ("Inductive Coupling Plasma Mass Spectrometry") purchased at the end of 2009 was pursued and infrastructural works were undertaken. Again, the financial situation of ITN prevented the completion of the installation of the equipment during 2010. It is anticipated that the ICP-MS will become operational during 2011, 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 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.

Research and Development activities:

During 2010, research and development activities were conducted at a sustained rhythm with the involvement of researchers, technicians, fellows and collaborators in national and international consortia conducting R&D activities and projects funded by the European Union (in the 6th and 7th Framework Programmes) and by the Portuguese Foundation for Science and Technology (FCT), among others.

Special efforts were undertaken to strengthen the involvement and to consolidate the activities of the UPSR in areas such as Computational Dosimetry, Internal Dosimetry, Biological Dosimetry and Radiobiology. Collaborative links were fostered with hospitals and research centres in topics related to the medical applications of ionizing radiation.

Activities and projects in the field of low dose radiation research were undertaken. ITN joined the MELODI (Multidisciplinary European Low Dose Initiative) platform. Involvement in research activities under the umbrella of several Working Groups of EURADOS and EURAMET was continued.

Technical Services:

The Environmental Radioactivity Group and the Measurement Laboratory conducted the National Environmental Radiological Survey including the monitoring of the areas around the former uranium mining sites and of the *campus* of Sacavém. The Radioprotection and Radioactive Waste Group performed activities associated to the licensing of radioactive sealed sources, the interim storage of radioactive waste, the detection of radioactive substances in scrap metal, the management of radioactive wastes on medical, and industrial facilities, and the verification of the radiological safety of installations, among others. The Dosimetry and Radiobiology Group pursued its technical activities related to the assessment of the safety of radiological installations, mainly in Nuclear Medicine installations and Radiotherapy vaults, in hospitals and clinics throughout the country, as well as to individual and environmental monitoring. The Laboratory of Metrology of Ionising Radiation performed the calibration and metrological verification of equipments. The available irradiation devices were used in support of R&D activities.

Participation in intercomparison exercises:

The UPSR staff involved in environmental radioactivity measurements and in nuclear analytical techniques and methods participated in intercomparison exercises organized by the International Atomic Energy Agency (IAEA), by the European Commission (EC) and other institutions.

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 and Masters Courses in Radiological Protection and Safety, in several Portuguese universities. A significant number of Master thesis and post-graduation works, supervised by UPSR researchers, was observed. The UPSR participated in the activities of the European platforms and networks namely EUTERP and CHERNE.

Participation in national and international technical and scientific committees:

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

Staff

Researchers

P. VAZ, Princ.(Agreg.)
F.P. CARVALHO, Princ.
M.J. MADRUGA, Princ.
M.A. NEVES, Princ.
C. OLIVEIRA, Princ.(Habil.)
J. ALVES, Aux.
R. TRINDADE, Aux.
A. D. OLIVEIRA, Aux.
I. PAIVA, Aux.
M. REIS, Aux.

J. CORISCO, Aux.
P. TELES, Aux.
S. di MARIA, Post-doc

Technical and Admin. Personnel

J. ABRANTES
J. CARDOSO
T. ANTUNES
L. PORTUGAL
G. L. SILVA
D. ALVES

J. OLIVEIRA
J. VENÂNCIO
L. SANTOS
M. A. LIBÂNIO
M. E. PACHECO
M. MARTINS (until Nov.)
M. SARAIVA
A. MOURATO
Y. ROMANETS
I. LOPES
L. MACHADO
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M. MALTA
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Fellows

A.C. ANTUNES
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A. BAPTISTA
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P. DUARTE

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A.R. GOMES
J. MELO
P. NOGUEIRA (until Feb.)
C. BORGES
E. ANDRADE
S. BARROS
C. CARRAPIÇO
R.F. LUÍS
A.BELCHIOR
C.FIGUEIRA
R. SARMENTO

Metrology Laboratory of Ionizing Radiation

Carlos Oliveira

The Metrology Laboratory of Ionizing Radiation (LMRI) has been involved in activities related with scientific, technical and legal metrology. A special attention was given to the LMRI Quality System (QS), due to the accreditation process that is involved in. Collaboration with Universities, national and international organizations and other ITN units were established and increased, in the framework of research projects.

Scientific and technical activities:

LMRI continues to participate in the European project in the framework of the EURAMET organization: JRP06 "Increasing cancer treatment efficacy using 3D brachytherapy". A new project elaborated in 2010 has been approved to start in September 2011, JRP13i "Ionizing Radiation Metrology for Metallurgical Industry". These projects arise from the implementation of the "European Metrology Research Programme" (EMRP) and are co-funded by the European Commission.

Two projects for the construction of the two air kerma primary standards are ongoing: a cavity chamber for ^{60}Co gamma rays and a free air chamber for low and medium X-ray energies (20 keV to 150 keV). The collaboration with other metrology laboratories is assured, namely with LNHB and BIPM.

The collaboration with the University has pursued, namely with the FCT – UNL (Faculdade de Ciências e Tecnologia - Universidade Nova de Lisboa). The results were, one master thesis has been presented, two master thesis have been realized and a new thesis has been accepted by the University to be performed at the LMRI during the next year.

A collaboration with the ESTeSL – Escola Superior de Tecnologia da Saúde de Lisboa do Instituto Politécnico de Lisboa took place with the realization of a traineeship.

A review of the LMRI 43 Calibration and Measurement Capabilities (CMC's) was started according the recommendations of the EURAMET and this includes a revision of technical procedures, uncertainty assessment and inter-comparison reports.

Legal activities:

The IPQ recognizes since April 2010 the LMRI as OVM (Organismo de Verificação Metrológica), necessary to perform legal metrology. Starting this date the metrological verifications is done according this status.

Concerning the legal metrology 20 medical dosimeters have been calibrated and 140 dosimeters and radiation monitors were metrological controlled. About 1200 TLD's dosimeters were irradiated.

Quality System

A technical audit to some LMRI calibration services was done, by the first time, with a European expert on the field of dosimetry. This visit was done with the support of IAEA. The objective of the mission was to realize a technical assessment of LMRI and its quality management system and also to find evidence of a national quality assurance for dosimetry in medical use of ionising radiation. Recommendations have been done for the LMRI, Government and AIEA. The quality management system with a special emphasis in the accreditation process has also been audited by a second entity, the Instituto de Soldadura e Qualidade (ISQ).

Internal collaborations

The LMRI has collaborated with all the Units of the Campus.

Technical assistance has been assured to the URSN during its annual maintenance of the RPI. The collaboration with the Radiation Dosimetry and Radiobiology Group (GDR) and the technical assistance to the Radioprotection and Radioactive Waste Group at UPSR has pursued. Collaboration with the Group Geochemistry & Luminescence on Cultural Heritage of UCQR in the framework of the *Radiart* project is realized. Some metrological services have been done to the UFA.

International organizations

Due to the activities on ionising radiations of LMRI, the ITN is the Designed Institute on the EURAMET organization.

The LMRI is recognised as a member laboratory of the IAEA/WHO network of the SSDLs and has participated in the TLD audit to the absorbed dose to water for ^{60}Co promoted by the IAEA.

Other activities

One of the members of the team, Luis Santos, is the Quality Manager of the UPSR QS in the Accreditation process and also gives support to management of the Data Base of the Environmental Radioactivity Group. Members of the Group participate on Computational dosimetry group of EURADOS.

Research Team

Researcher

C. OLIVEIRA, Princ., (Habil.), Group Leader

Technical Personnel

J. CARDOSO
L. SANTOS, (50%)
A. CASTRO

Dosimetric quantities calculated for two brachytherapy sources using Monte Carlo codes.

Milton Rodrigues, Luis Portugal, João Cardoso 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.

In this work dosimetric quantities were calculated as described in TG-43 (1) of the AAPM using Monte Carlo simulations for two brachytherapy seeds: one used for low rate applications, the Bebig model I25.S06 (a ^{125}I source) and another used for high dose rate applications, the Nucletron MicroSelectron V2 source (^{192}Ir). The results have been obtained using two different MC codes, the MCNPX and the PENELOPE code.

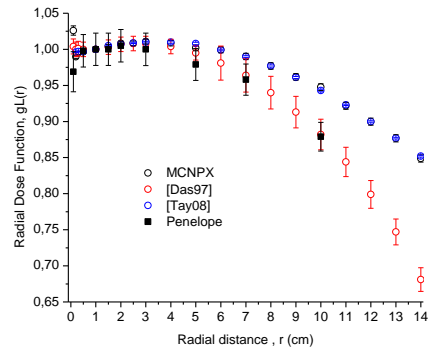
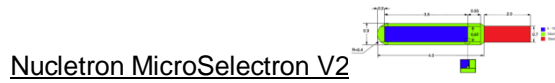


Fig 3 Radial dose function as function of radial distance.

Bebig model I25.S06

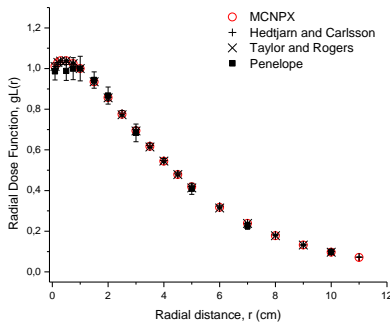


Fig 1 Radial dose function as function of radial distance.

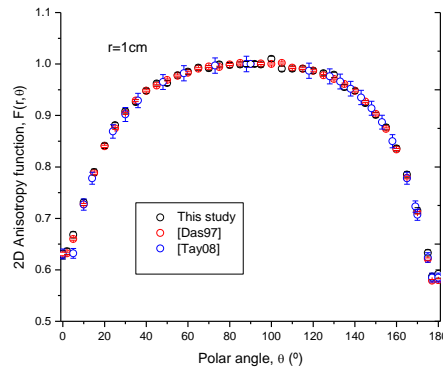


Fig 4 2D anisotropy function as function of polar angle for a radial distance of 1 cm.

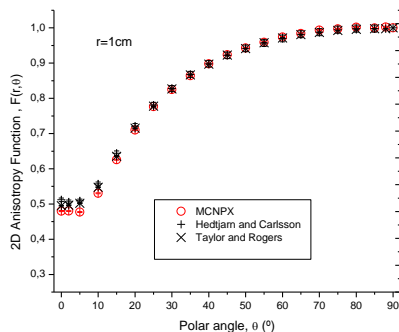


Fig 2. 2D anisotropy function as function of polar angle for a radial distance of 1 cm.

The radial dose functions are quite different for the two sources. This is due to the different energy spectra. The higher energy of the ^{192}Ir determine a maximum of the function near the 4.5 cm while for the ^{125}I source the maximum occurs near 1 cm of the source.

The anisotropy function is obviously symmetric for the Bebig seed but for the V2 source its values are lower for the smaller polar angles which correspond to the side of the stain steel cable.

Reference

Rivard, M. J., Coursey, B. M., DeWerd, L. A., Huq, M. S. Ibbott, G. S., Mitch, Nath, R., Williamson, J. F. Update of AAPM Task Group No. 43 Report: A revised AAPM protocol for brachytherapy dose calculations. Medical Physics 2004; 31: 633–674.

DEVELOPMENT OF A NEW IONIZATION CHAMBER, FOR HP(10) MEASUREMENT, USING MONTE CARLO SIMULATION AND EXPERIMENTAL METHODS*J. Cardoso, H. Silva¹, C. Oliveira*

An ionization chamber that directly measures the quantity personal dose equivalent, Hp(10), is used as a secondary standard in some ionizing radiation metrology laboratories. This ionization chamber was first developed by Ankerhold, at PTB and some years later a similar chamber has been developed and studied in the Metrology Laboratory of Ionizing Radiation (LMRI) of ITN. The work realized recently developed a new ionizing chamber. Some of the basic metrologic characteristics of ionizing radiation detectors were investigated on this chamber, like energy response, angular response, accuracy and a special attention was given to geometrical aspects of the ionization chamber. This was done both by experimental and Monte Carlo simulation work. The objective of this work was to study the influence of all components of the IC on response considering some geometrical modifications. In order to investigate the response of the IC as a function of energy for different dimensions, eleven ionization chambers were designed and simulated. A detailed study of the interaction of X-rays with the several components of the Hp(10) ionization chamber was performed and the results of the simulation studies led to a new ionization chamber, IC₁, that was constructed and its response was compared with the previous LMRI_ chamber, IC₀. From the simulation results there is a geometry which seems to represent a good compromise between a good response and its weight. According to these results a new ionization chamber, IC₁, was constructed and its response was experimentally investigated and compared with the IC₀ chamber. Experimental tests were performed using the X-ray radiation qualities of the narrow spectral series, described in the ISO 4037-1, for angles of incidence α between the photon beam and the normal to the slab phantom's front surface of 0°, 45°, 60° and 75°. The response of the ionizing chamber as a function of photon energy and incidence angle has been studied and the calibration coefficient, N_H was obtained by applying ISO conversion coefficients. Its value is N_H = 5.324 × 10⁶ Sv/C with an expanded uncertainty (k=2) of 6.0 %. The uncertainty was calculated combining all the uncertainty components of the measurement. The main contributions to uncertainties are related to the measurement itself. The new chamber has the advantage to have a weight reduced by a factor of 4 (4 kg vs 16 kg) relatively to the previous chamber. This is a great advantage for the portability of the instrument. For the radiation qualities tested, the ionization chamber is fully characterized. The correction factors of the new constructed chamber are lower than for the previous chamber. Some fluctuations were found and are assumed to be linked with electrode construction.

¹FCT-UNL**Characterization of Mammography Radiation Qualities at LMRI***D. Góis¹, J. Cardoso, C. Oliveira*

New radiation beam qualities have been established and characterized at the LMRI using the tungsten-anode low energy x-ray tube with molybdenum filters and molybdenum plus aluminium filters. These radiation qualities simulate the radiation beams used in clinical mammography. The purpose of this study is to have the conditions in order to perform the metrological control of dosimeters used in mammography. The X-ray equipment of LMRI has a W anode and in consequence, the international standard IEC 61267 has been used only for the procedures relatives to the characterization of the radiations qualities.

To characterize the radiation qualities the values of HVL and the homogeneity coefficient h have been determined. The applied potential was 23 kV to 31 kV with a step of 1 kV, and 35 kV, 40 kV and 50 kV using 0.06 mm or 0.03 mm of Mo as filtration with and without additional filtration (2 mm Al). The results of the *HVL* (mm of Al) are compared with the values of other laboratories (PTB and BIPM). The dosimetry will be performed using a new ionization chamber, the PTW Mammo Chamber type 34069, purchased recently but requiring a previous calibration scheduled at BIPM in 2011.

¹FCT-UNL**Project, construction and characterization of a portable irradiator for metrological verification of fixed area monitors.***Ana Carvalho¹, J. Cardoso, C. Oliveira*

The purpose of the work is the project and characterization of a portable irradiator equipped with a ¹³⁷Cs source to be applied to the metrological verification of the fixed area monitors. This equipment measures the ambient dose equivalent, H*(10). The irradiator has a cylindrical shape with two parallel plane bases connected to two small cylinders which fill the respective cylindrical cavities. One of these cavities contains the source. The second cylinder is only removed when the irradiator is operating. The maximum dose at 1m distance is 3 µGy/h. The total weigh is approximately 3 kg. The characterization of the field has been achieved determining the profile, horizontal and vertical, of the radiation field both experimentally and using a Monte Carlo code. The height half width varies between 20 cm and 40 cm for distance to the source from 20 to 40 cm for both profiles. Using an ionising chamber calibrated at H*(10), this quantity has been determined for distance up to 1.5 m. When in operating the irradiator need to have attached a tube to support it and to assure a fixed distance to the area monitor. The influence of this tube has been analysed and its perturbation quantified. The influence of the proximity of a wall near the monitor to be controlled also has been studied.

¹FCT-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 LMRI quality system has been audited twice. One of the audits was carried out, during three days, by Hans Bjerke, chair of the Technical Committee for Ionizing Radiation of EURAMET. The objective of the mission was to realize a technical assessment of LMRI and its quality management system and also to find evidence of a national quality assurance for dosimetry in medical use of ionising radiation. The audit has focused with special attention to the CMC's. Recommendations have been done for the LMRI, Government and AIEA. The second audit was realized by ISQ (Instituto de Soldadura e Qualidade) and was focused on accreditation process and the techniques to be accredited.

As has happened in recent years the LMRI participated in the TLD audit to the absorbed dose to water for ⁶⁰Co promoted by the AIEA.

The Metrology Laboratory of Ionizing Radiation (LMRI) submitted for accreditation three 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.

Calibration and Measurement Capabilities (CMC's)

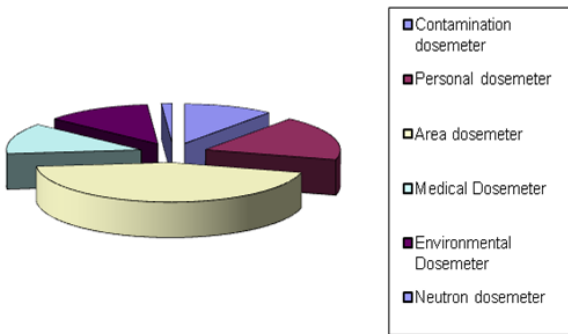
According to the recommendations of the EURAMET a revision of the CMC's, namely the revision of procedures, uncertainties assessment, update of inter-laboratorial comparison, have been initiated.

SERVICES

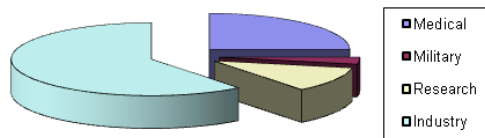
L. Santos, J. Cardoso, A. Castro, C. Oliveira

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 n°. 1106/2009 dated of 24 of September. During 2010 were calibrated 160 dosimeters. The following figures can quantify the work done in this particular area.

In 2010, the LMRI, have irradiated personal dosimeters for the reader system calibration of two private companies.



Instruments calibrated by users activity.



Instruments calibrated by type of use.

INTERNAL SERVICES

LMRI collaboration with ITN Groups

L. Santos, J. Cardoso, C. Oliveira

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; five area monitors measuring system MGP C/EIP 51 equipped with ionisation chambers; four area monitors measuring system Automess 632.1 equipped with Geiger-Muller detectors; the fission products detection system, Tracerlab, Inc. MWP-1A; the noble gas monitor system Mirion NGM 204L 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 three personal electronic monitors, two area monitors and one contamination monitor.

Unit of Physics and Accelerators (UFA)

In 2010 the LMRI has carried out the control metrological of two radiation monitors.

**Unit of Chemical and Radiopharmaceutical Sciences (UCQR)
Geochemistry & Luminescence on Cultural Heritage Group**

In the framework of the *Radiart* project a few TLD's have been irradiated.

Unit of Radiological Protection and Safety (UPSR)

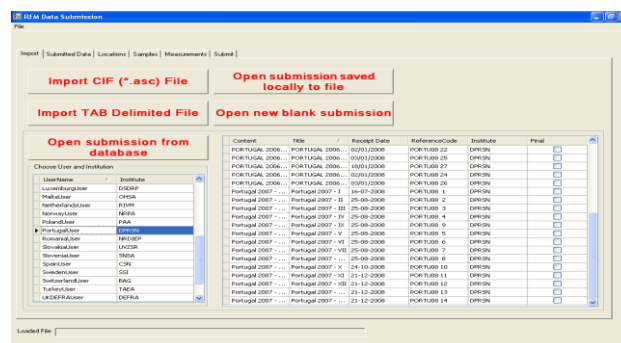
Dosimetry and Radiobiology Group

In 2010 about 1200 TLD dosimeters 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 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 0.25 Gy to 3.0 Gy using a source of ⁶⁰Co. About 50 irradiations have been carried out.

In the scope of a master degree, one ionizing chamber was calibrated in X-ray N-120 radiation quality.

Environmental Radioactivity Group

The technical support to UPSR - Environmental Radioactivity group database (SIAC) 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 SIAC 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 300 k€.

Current research activities are ongoing to investigate the levels of radioactive contamination in the atmosphere (aerosols) aquatic and terrestrial environments.

The Group participated in collaboration with the Measurement Laboratories in the following international inter-comparison exercises: determination of natural and artificial radionuclides in moss-soil and spiked water organized by the IAEA/ALMERA (Seibersdorf, Austria); determination of natural radioactivity, ¹³⁷Cs and ⁹⁰Sr in soil organized by the EC (IRMM, Geel, Belgium) and determination of natural and artificial radionuclides in foodstuff (ash) organized by the Consejo de Seguridad Nuclear (CSN, Spain). The results published in 2010 were in good agreement/compatible with the reference values.

In 2010, was given continuation to the collaboration with the Radioactivity Environmental Monitoring (REM) group of the European Commission located at the JRC (Joint Research Centre) in Ispra (Italy), on the development of a European Atlas of Natural

Radiation, including radon mapping based on indoor radon measurements.

During 2010, several interventions were carried out on the Radionuclide Particulate Station (RN53) at S. Miguel, Azores. A new detector was installed and calibrated. The problems detected during the testing phase were addressed and solved and a new testing and tuning phase begins. On November 2010 the certification visit was carried out (by CTBTO, Alenia and ITN) and all the required tests were performed. The station was now formally certified since 23rd of December and providing data to the International Monitoring System in the framework of the CTBT (Comprehensive Nuclear Test Ban Treaty).

The technical services developed by the Group were 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 306/2007), mineral waters and indoor radon measurements (Decree-Law 78/2006; NT-SCE-02). The Group income of these technical services was about 54 k€.

The accreditation procedure of three radioanalytical techniques was submitted to the accreditation body (IPAC) in October 2009 and the quality audit concession was foreseen for 2010. This year, an internal quality audit to these techniques, according to the ISO/IEC 17025 requirements, was performed by two auditors from ISQ (Instituto Soldadura e Qualidade).

Members of the Group were involved in several committees from IAEA and CTBT.

During this year members of the Group were involved in education and training activities in the fields of environmental radioactivity and radiological protection.

Research Team

Researchers

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

Fellows

A.R. GOMES, FCT grant
E. ANDRADE, FCT grant (since October 2010)
H. FONSECA, FCT grant (until August 2010)
J. MELO, FCT grant

Technical Personnel

A. LIBÂNIO
A. MOURATO
I. LOPES
J. M. OLIVEIRA (70%)
M. M. MALTA

Radiological Environmental Monitoring Programmes

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

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”.

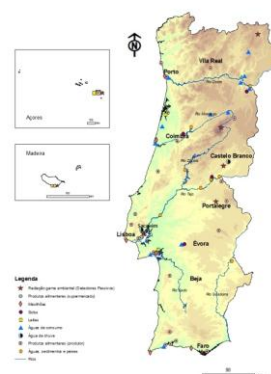
The Radiological Environmental Monitoring Programmes planned according to Article 35 of the EURATOM Treaty include the Programme at a National Level, established by law in 2005 and which execution was legally attributed to ITN (Decree-Law 138/2005, 17th August), the Source Related Programme for the ITN *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 in Portugal was performed. Field missions were carried out in several counties of the North-centre of Portugal in the regions of Guarda, Nelas, Mangualde, and in the hydrographic basin of Mondego River. Water, soil, and vegetable samples were analysed for uranium series radionuclides. 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 2010 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 2000 analyses were performed for the determination of artificial and natural radionuclides, using gamma and alpha spectrometry, alpha/beta measurements and liquid scintillation technique. Integrated measurements of the ambient dose equivalent with thermoluminescent dosimeters were also performed. The results show that the Portuguese population was not exposed to radioactive contamination levels higher than the radioactive background. Therefore, there is no need to adopt any measures for radiological protection of the population. All the data are published in Internal Reports 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, I. Lopes, J. Abrantes, L. Silva, L. Torres, L. Portugal, M. Malta, A. Libânio, A. Mourato, G. Silva, J.M. Oliveira, L. Santos, A. Batista, A.R. Gomes, G. Carvalhal, H. Fonseca, J. Melo, M. Pereira. Programas de Monitorização Radiológica Ambiental (Ano 2009). *Internal Report UPSR, Série A, n°37/10, ISBN 978-989-96542-5-9, Depósito Legal 194022/03, pp. 146.*

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 $^{239+240}\text{Pu}$, 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.

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, I. Paiva, M. Gonçalves¹

This study concerns the characterization of geomaterials from “Raña” deposits for radiocaesium adsorption and is part of a research project KADRWaste, funded by FCT² 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. During this year adsorption/desorption experiments of caesium in “Rañas” (fraction <63µm) using continuous flow Teflon reactors were carried out at different pH values, ionic strength and initial caesium concentrations. The caesium in liquid phase was quantified by ICP-MS at APA (Agência Portuguesa do Ambiente) laboratories. The experimental scheme using the Teflon reactors designed and adapted to this study have shown to be suitable for the proposed objective. These experiments were performed at the Faculty of Sciences of Lisbon, Geology Department. The results obtained were essential to plan the long term experiments with radiocaesium that will be carried out at ITN to study the influence of contact time, flow, ionic strength, radiocaesium concentrations, etc., in the ^{137}Cs adsorption/desorption on geomaterials.

¹Geology Department, Faculty of Sciences, University of Lisbon

²Portuguese Foundation for Science and Technology

Accreditation of Radioanalytical Techniques

M.J. Madruga, I. Lopes, A. R. Gomes, J. Melo, J. A. Corisco

Regarding the quality assurance of radioanalytical techniques and following the work developed in 2009, improvements were introduced on the management and technical procedures, for instance, on the preparation of radioactive standard solutions to be used on analytical standards or for radiochemical purposes. In February 2010, an internal quality audit, according to the ISO/IEC 17025 requirements, was performed for the three techniques, global alpha/beta in waters using proportional counters or Liquid Scintillation Counting (LSC) and tritium determination in waters by LSC. The audit was carried out by two auditors from ISQ (Instituto de Soldadura e Qualidade). During the audit a systematic and independent examination was carried out to determine whether quality activities are implemented effectively and are suitable to achieve the objectives. Small nonconformities were identified and corrective actions were implemented.

Three papers concerning the quality assurance of these radioanalytical techniques were presented at the Liquid Scintillation Conference held in Paris (France) in September 2010. Two members of the GRA participated at the

“VI Jornadas sobre Calidad en el Control de la Radiactividad Ambiental” held in Cáceres (Spain) from 20 to 23th September 2010.

In the framework of the quality system some improvements were introduced in the laboratorial infrastructures. The laboratory for the manipulation of radioactive sources (LMFR) intended to serve as a common facility in support of all the activities of the UPSR, whenever manipulations of standard radioactive solutions and intercomparison radioactive samples are implicated, was recently (2009-2010) through extensive remodelling. New equipment – table tops, storage cabinets, gas extraction cabinet, air conditioning and temperature/humidity probe were installed. The samples storage room was refurbished and air conditioning and temperature/humidity probe were also fixed in order to maintain the samples in a good state.

Total column and surface ozone variability over the Iberian Peninsula: Dynamical and chemical atmospheric factors - DYNOZONE

M. Reis, M. J. Madruga, H. Fonseca, L. Silva

The DYNOZONE project was approved and funded by FCT. Is a cooperation project between New University of Lisbon, Nuclear and Technological Institute, Aveiro University and Fernando Pessoa Foundation for Teaching and Culture. The project officially started on October 2010. The main objectives of the project are to identify and justify, on a scientific base, the no photochemical origin of some ozone events, namely the stratosphere-troposphere exchange contribution to elevated surface ozone concentrations, as opposed to local production or long range transport from external pollution sources. The project team will analyse surface ozone concentration long records along with radionuclides time series available for Lisbon. The chemical-dynamical processes of such events will be studied by means of the EURAD model applications, for which a data assimilation procedure will be developed.

Indoor Radon Mapping

M. Reis, H. Fonseca

Continuation of the collaboration with the REM (Radioactivity Environmental Monitoring) group of the JRC (Joint Research Centre) on the development of a European Atlas of Natural Radiation, including radon mapping based on indoor radon measurements.

SERVICES

1. Radioactivity in Drinking and Mineral Waters

M.J. Madruga, J. Melo, A.R. Gomes, A. Libânio, I. Lopes, F.P. Carvalho, J.M. Oliveira

Regarding the evaluation of the radioactivity levels in drinking waters (Decree-Law n°306/2007) the UPSR was requested by Water Suppliers to carry out the determinations of global alpha, global beta, Tritium, ^{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 n°84/90). The radiological study included analyses of ^{226}Ra and global beta. Several enterprises often request this radiological study.

During 2010, a total of about 300 analyses were performed.

2. Indoor Radon

M. Reis, H. Fonseca, E. Andrade

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 2010, about 900 measurements were performed.

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 ^3H in biological samples for cancer research purposes (by request of Radiopharmaceutical Sciences Group of UCQR).

Regarding the external quality control of the measurements, during 2010 the LM group has participated, together with the GRA, in several international intercomparison exercises organized by the International Atomic Energy Agency (IAEA), the European Commission (EC) and the Consejo de Seguridad Nuclear (CSN), including samples of different matrices (water, soils and foodstuff ashes) with natural and artificial radionuclides. Furthermore, the gamma spectrometry Laboratory has also participated in a gamma spectrometry proficiency test

organized by the National Physical Laboratory (NPL), in the *Menu2010* interlaboratory emergency response comparison exercise sponsored by the Food Emergency Response Network of the USA, and in ICRM Part II exercise on intercomparison of the methods used for computing the coincidence summing corrections.

The group remains involved in the ongoing *KADRWaste* project, mainly through the radiological characterization of soil and rock samples using high resolution gamma-ray spectrometry.

Collaborative activities with the Dosimetry and Radiobiology Group (GDR) were maintained, regarding the application of Monte Carlo simulation techniques to computational efficiency calibration of HPGe detectors, computation of self-attenuation and coincidence summing correction factors.

Giving continuity to the accreditation process, during this year internal quality audits were carried out by the Instituto de Soldadura e Qualidade (ISQ) to the following techniques: gross alpha/beta in waters using GPC and LSC, tritium in waters using LSC and gamma spectrometry using HPGe detectors.

During 2010, the Measurement Laboratories also received a great number of study visits, mainly from groups of students of secondary schools and universities.

Regarding the education and training, during 2010:

- Two group members received technical training (IAEA financed fellowships) under the framework of the IAEA Project RER/0/031;
- Two group members concluded the post-graduation studies (DFA) on Radiological Protection and Safety, at the Technical University of Lisbon.

Research Team

Researcher

M. REIS (75%), Aux., Group Leader

Fellow

G. CARVALHAL, FCT grant

Technical Personnel

L. SILVA

J. ABRANTES

L. TORRES

J.M. OLIVEIRA (30%)

G. SILVA

Comparison of Methods Used for Computing the Coincidence Summing Corrections

G. Carvalhal, L. Silva, M. Reis

Objectives

Coincidence summing effects occurs when two or more gamma-rays (or annihilation photons or X-rays) are emitted in cascade following the decay of the same nucleus, and are recorded simultaneously within the resolving time of the detector, leading to a loss of counts in the individual photo-peaks while incrementing the counts in the sum peak. Due to the common use of high volume detectors, together with short distance measurements, this phenomenon should be carefully addressed. Different methods could be used to compute coincidence summing correction factors, namely empirical methods, numerical computation or Monte Carlo simulation techniques. Nowadays, the attention is mainly focused on the use of Monte Carlo based codes. Keeping that in mind, the Gamma Spectrometry Working Group of the International Committee for Radionuclide Metrology (ICRM) organized an international exercise on the intercomparison of the methods used for computing the coincidence summing correction. The Gamma Spectrometry Laboratory of the Measurements Laboratories has participated on the Part II of that exercise, focused on volume sources.

Results

The intercomparison was focused on the calculation of corrective factors for ^{152}Eu and ^{134}Cs , considering several energies and three types of volume samples, using three different screens between sample and detector (Plexiglas, copper and Mylar). The participant laboratories received the experimental spectra corresponding to the different acquisition conditions

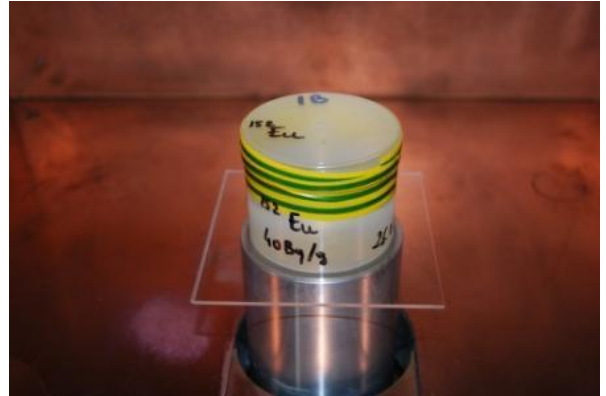


Fig 1 Acquisition set-up with ^{152}Eu volume sample on top of the detector and the Plexiglas screen.

and were asked to compute the coincidence summing corrective factors for both radionuclides and for all acquisition combinations.

Different codes were used for the participant laboratories: GESPECOR, TrueCoinc, CSCOR, LABSOCS, ETNA+MCNP, CCCC and ETNA+PENELOPE.

As example of the preliminary results, the Figure presented below shows the mean value of the coincidence summing corrective factor for the main energies of ^{152}Eu , computed by the participants for one of the volume samples at contact with the detector and using the Plexiglas screen.

Published Work

G. Carvalhal, Exercise ICRM 2009-2010: Intercomparison of the methods used for computing the coincidence summing corrections – Part II, *ICRM GS Workshop*, Italy, Rome, 18-19 October 2010.

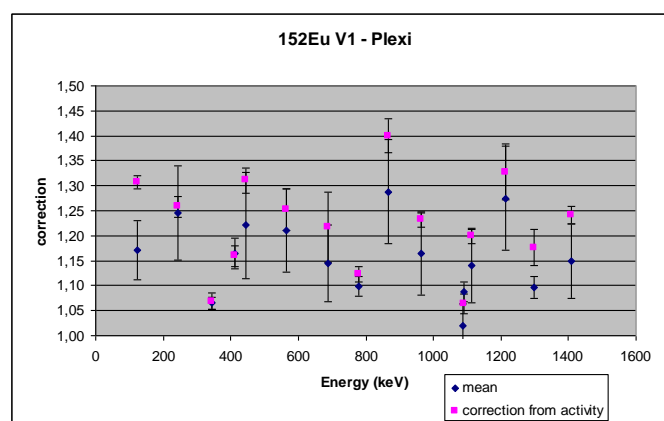


Fig 2 Mean correction factor for ^{152}Eu according to the acquisition set-up showed above

Application of Monte Carlo Techniques to Gamma Spectrometry

G. Carvalhal, L. Silva, R. Luis, J. Bento, P. Nogueira, P. Teles, P. Vaz

During 2010 was given continuity to the collaborative activities between the Measurement Laboratories (LM) and the Dosimetry and Radiobiology Groups (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 by using different Monte Carlo codes. As a result of those activities two papers were published in international journals and one communication was presented in an international Conference.

Accreditation of Radioanalytical Techniques

J. Abrantes, G. Carvalhal, M. Reis, L. Silva, G. Silva

During 2010 the LM group remains involved in the preparation of the accreditation process according to ISO/IEC 17025 standard. Internal quality audits were carried out by the Instituto de Soldadura e Qualidade (ISQ) to the following techniques: determination of gross alpha/beta activity in waters by Gas Proportional Counting (GPC) and Liquid Scintillation Counting (LSC), determination of tritium in waters by LSC and determination of gamma emitters in solid and liquid matrices using high resolution gamma-ray spectrometry.

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), two group members have participated in technical training programmes (IAEA financed fellowships, two weeks duration) related to the establishment of QA/QC practices: one in gamma spectrometry with HPGe detectors and the other regarding the measurement of alpha and beta emitters by Gas Proportional Counters and Liquid Scintillation Counters. The training took place at the Physics, Chemistry and Instrumentation Laboratory of the IAEA (Seibersdorf), in the first case and at the Department of Analytical Chemistry of Barcelona University and at the Institute of Energy Technology of the Technical University of Catalunya, in the second case.

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 2010, 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 19 kEuros.

Dosimetry and Radiobiology Group

Pedro Vaz and Octávia Monteiro Gil

The synergies of the competences held by the Dosimetry and Radiobiology Group (GDR) researchers and technicians were further strengthened, in order to address and to respond in a more efficient way to the multidisciplinary, cross-cutting leading-edge scientific and technical issues in Dosimetry and Radiobiology, including low dose radiation research.

The main components of activity of the GDR are Individual Dosimetry, Computational Dosimetry, Internal Dosimetry, Biological Dosimetry, Radiobiology and Radiological Safety Assessment of installations.

The competences in several radiobiology and bio-dosimetric techniques namely dicentric, micronuclei, γ -H2AX and COMET assays, were strengthened. The existing competence in Computational Dosimetry, (in Monte Carlo simulations) was deployed in support of radiological protection, dosimetry and shielding assessment studies of nuclear technology facilities, of radiological installations, and of the modelling of medical radiological equipments and of HPGe-based detection systems, including the Whole Body Counter operated by the GDR. Biokinetic models and Internal Dosimetry studies were undertaken.

Researchers and fellows from the GDR have:

- Participated in R&D projects conducted and submitted by international consortia, in the E.U. 7th Framework Programmes or in collaboration with CERN;
- Submitted research projects to the Portuguese Foundation for the Science and Technology;
- Participated in the activities of EURADOS WGs.

Medical applications of ionizing radiation

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. Activities related to the dose assessment and computational modelling of medical radiological equipments were undertaken, namely in mammography, in Computed Tomography (CT) and in Fluoro-CT.

Low dose radiation research

The occupational or environmental exposure to low radiation doses and the medical exposures to ionizing radiation for diagnostic or therapy purposes are currently very hot scientific- and regulatory- related topics and issues. Major findings in the biological effects of radiation should allow to narrow the persisting uncertainties about the mechanisms of response of cells, tissues and biological systems in the

range of low doses, what will pave the way for developments of the international system of Radiation Protection. The ITN participated as a full member in the activities of the EU-platform MELODI (Multidisciplinary European Low Dose Initiative”) namely in the drafting of a roadmap and a strategic research agenda for the low dose research in Europe.

Response to radiological emergencies and accidents

Activities initiated in recent years were pursued aiming at increasing 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 (modelling issues involving biokinetic models), Computational Dosimetry (Monte Carlo modelling and simulations) and Biological Dosimetry (using the aforementioned assays, amongst others).

Technical services

The GDR continued to operate its individual dosimetry and monitoring services and to perform the radiological safety assessment of radiological installations (radiotherapy installations and nuclear medicine services throughout the country). The radiological safety assessment of the X-ray scanners in operation in the Ports of Mozambique and Cape Verde was performed upon request of the local authorities.

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.

Higher Education and Training

Several researchers maintained regular collaborations with Portuguese universities and higher education institutions, teaching Radiation Protection- and Dosimetry-related disciplines in the framework of Masters and post-graduation programmes and supervised several graduation, Masters and Ph.D. theses. Several technicians and fellows finished post-graduation diplomas and Masters thesis and participated in international training courses in radiation protection, dosimetry and radiobiology.

International and national representation activities

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., (Agreg.)
M.A. NEVES, Princ.
J. ALVES, Aux.
O. MONTEIRO GIL, Aux.
A. D. OLIVEIRA, Aux.
P. TELES, Aux.
S. di MARIA, Post-Doc

Technical and

Admin. Personnel

T. ANTUNES
M. MARTINS (until Nov.)
M. SARAIVA
S. RANGEL
Y. ROMANETS

Fellows and Collaborators

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V. MARTINS
A. BELCHIOR
J. BENTO
C. BORGES
C. CARRAPIÇO
C. FIGUEIRA

R. F. LUIS
M.N. PEREIRA
S. BARROS
R. SARMENTO

Implementation of a dose response curve for dicentric chromosomes

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

The development of a dose response curve, which can be applied to the Portuguese population in any radiological emergency, is being held at ITN. This work already began in the previous year. Until now, this kind of study was never done in Portugal. The *in vitro* dose response curve is being performed with a sample of 16 healthy, non-smoker individuals, from both genders and in the range of 20 to 60 years (two donors per gender and interval of age). To achieve this objective we have already irradiated samples of peripheral blood lymphocytes from 13 donors with doses from 0 to 3 Gy air kerma, using a ⁶⁰Co source locate at LMRI/ITN. Per dose and for each individual, 200 metaphases were scored by two independent scorers and an additional scorer was used for aberrant cells confirmation. Until now, a set of 18,200 metaphases with 46 chromosomes were analyzed. Dicentric chromosomes were the chosen endpoint, since they are almost exclusively induced by ionizing radiation, being the characteristic chromosomal aberration for radiation exposure. A clear dose-dependent increase in terms of dicentric chromosomes was observed for all donors and at the higher dose level a larger intervariability among individuals was seen (Figure 1).

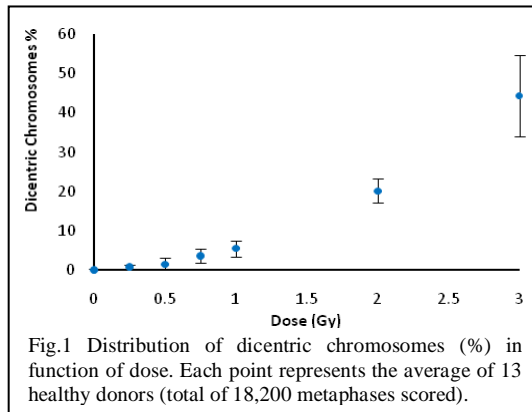


Fig.1 Distribution of dicentric chromosomes (%) in function of dose. Each point represents the average of 13 healthy donors (total of 18,200 metaphases scored).

Dose response curve using cytokinesis-blocked micronucleus assay

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

We have started the improvement of a dose response curve for biological dosimetry in case of radiation exposure, using the cytokinesis-blocked micronucleus (CBMN) assay. This is the first time that such study is undertaken for Portuguese individuals. The CBMN assay is an alternative method to the analysis of metaphases, because it is easier and allows faster evaluation of samples. Our study aims to evaluate the correlation among the

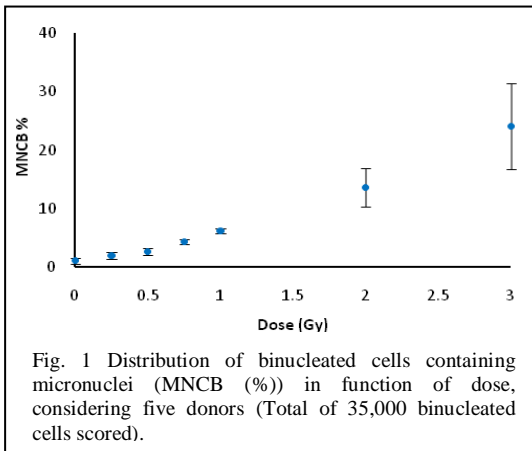


Fig. 1 Distribution of binucleated cells containing micronuclei (MNCB (%)) in function of dose, considering five donors (Total of 35,000 binucleated cells scored).

different biomarkers, micronuclei and dicentrics, in order to propose the use of CBMN assay for a rapid triage in cases of malevolent acts or mass casualty situations, where rapid evaluation of biological effects induced by radiation exposure and dose estimation is mandatory. Whole blood samples of five healthy donors were irradiated *in vitro* with doses from 0-3 Gy air kerma, using a ⁶⁰Co source locate at LMRI/ITN. Per dose and for each individual a total of 1,000 binucleated cells were analyzed in terms of micronuclei frequency. Figure 1 shows a dose-dependent increase in the level of genetic damage induced by ionizing radiation, considering the five donors already studied. Future work will consider the study of more individuals in order to propose the CBMN assay for rapid radiation exposure screening purposes.

γ-H2AX-new technique implementation using peripheral blood human lymphocytes

O. Monteiro Gil, A. Sebastião Rodrigues¹

We are implementing at ITN a new technique for detection of DNA lesion induced by ionizing radiation (IR) with the help and knowledge of Genetic Department of UNL. A DNA double-strand break (DSB) is a high cytotoxic form of DNA damage which, if not correctly repaired, can initiate genomic instability, chromosome aberrations and may eventually lead to cancer. Exposure to IR induced the phosphorylation of H2AX in the vicinity of a DSB (green spot), the greater the number of foci the greater the damage induced. This is a very important bioindicator to biological dosimetry.

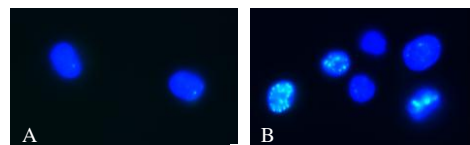


Fig. 1 Foci of γ-H2AX. (A) without exposition; (B) with exposition to the clastogenic agent. (A.S. Rodrigues, 2010)

¹ Genetic Department UNL

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

A.S. Fernandes¹, V. Martins, N.G Oliveira¹, 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) as evaluated by the cytokinesis-blocked micronucleus assay.

¹ CBT-iMed.UL /FFUL

Evaluation of the cytotoxicity induced by α radiation in an A549 cell line

A. Belchior, O. Monteiro Gil, P. Almeida¹, P. Vaz

The biological effects induced by α -radiation (²¹⁰Po), both direct and untargeted, in a human lung adenocarcinoma epithelial cell line (A549) were quantified with cytokinesis blocked micronuclei technique. The

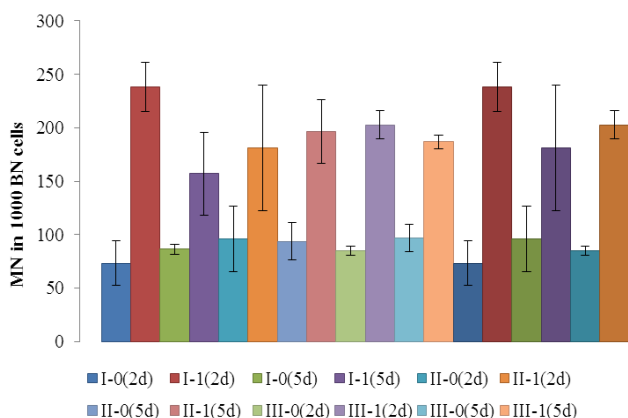


Fig 1 The controls are labeled as I-0, II-0, III-0 and the irradiated cultures as I-1, II-1, III-1. Early and delayed effects are labeled with 2d and 5d (2 and 5 days after exposure), respectively. Data represent the average of 3 independent experiments, \pm S.E.M.

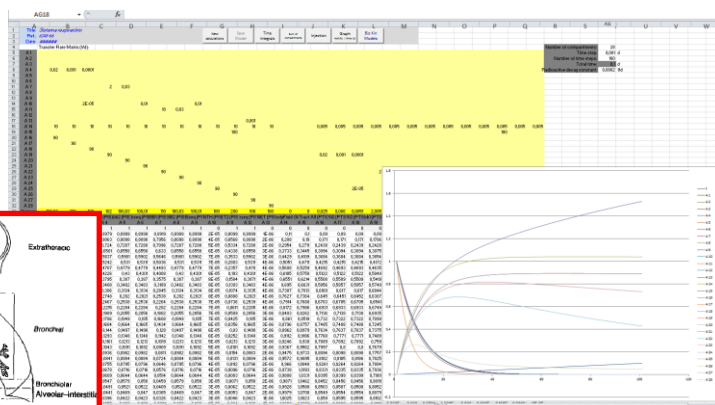
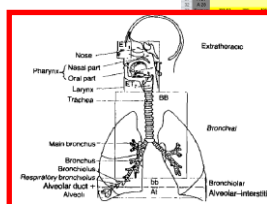
untargeted study includes; group I-irradiated cells (1Gy) cultured with fresh medium, group II-unirradiated cells cultured with irradiated medium previously filtered and group III-irradiated cells (1Gy) cultured after centrifugation with fresh medium. By direct exposure an increase in the number of cellular lesions as a consequence of increasing absorbed dose value is observed. At day 2 after cell irradiation, a more evident increase of the number of micronuclei (MN) per binucleated (BN) cell in group I was observed when compared to group III. Group II shows a clear increase in the frequency of MN when compared to the control. The delayed response of cells to radiation is similar to the early response. But, in Group II, the comparison of results obtained for delayed and earlier responses, one can notice an increase in the number of MN in the delayed response.

¹ IBEB-Fac. Ciências, UL

BioKinModels – Human respiratory tract

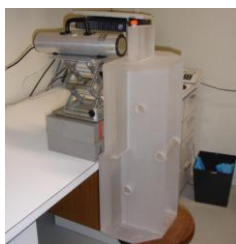
A.D. Oliveira

BioKinModel is a bio-kinetic models tool aiming to determine radiation doses received by individuals from radionuclides which enter the human body. The well-known ICRP Human Respiratory Tract model was implemented in the BioKinModels format.



Thyroid monitoring for assessment of I-125 contamination, using a NaI scintillator detection system

J. Bento, M. Neves, P. Teles



In addition to the WBC calibration, a portable detecting system using a NaI scintillator was also calibrated for thyroid measurements, using a PMMA phantom (RMC-II) and a I-125 source. Quality assurance of the equipment is performed recurrently. It is of major importance, as Iodine contamination cases are among the most common, thus improving ITN's emergency preparedness. This detecting system had a practical use in 2010, when five measurements had to be performed in relation to the suspicion of a possible accidental incorporation of I-125.

In vivo monitoring activities in internal dosimetry: recent calibrations using a BOMAB phantom

P. Teles, J. Bento, S. Barros, M. Neves, P Vaz



There have been remarkable improvements in the competences of UPSR in the framework of internal dosimetry activities. A new calibration of the whole body counter (WBC) was performed using a recently acquired BOMAB phantom, one of the industrial standard anthropomorphic phantoms used for these purposes. The WBC is now prepared to perform whole body scans and detect radionuclides emitting between 88 keV and 1836 keV, featuring low detection limits and acceptable minimum detectable activities. Along with the experimental calibration, Monte Carlo simulations were also performed, validating a computational model of the WBC and reproducing with good accuracy the measured detection efficiencies. In the future, this model will be extended to include mathematical and/or voxel phantoms that, in addition to being inexpensive will overcome the physical limitations of the experimental calibration.

Internal contamination assessment activities of Nuclear Medicine staff in Portugal

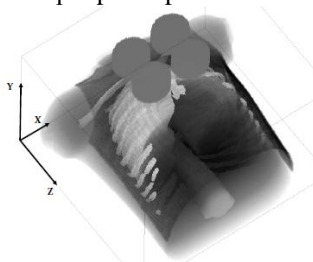
J. Bento, P. Teles, M. Neves

During 2010, a great effort was devoted to the assessment of the need to create and implement nationwide, a routine programme for internal monitoring of the Nuclear Medicine staff. This effort was put to practice by warning physicians and medical physicists against the risks of internal contamination in Nuclear Medicine, following the International Atomic Energy Agency (IAEA) guidelines, and disseminating ITN's competence in performing routine monitoring using the available equipment in our facilities. Several visits to key Nuclear Medicine services in hospitals in Lisbon, Porto and Coimbra, were undertaken, where insight into which are the most common practices in Nuclear Medicine, as well as which safety and protection measures are put in practice in these services was gained. Moreover, an assessment of the need for the internal monitoring of the Nuclear Medicine workers in the visited institutions was carried out using IAEA criteria, published in the safety guide RS-G-1.2. These criteria are based on the type and amount of radionuclides handled and on the protection and safety measures employed when handling them. A series of reports to the participating institutions is being prepared, as well as an article with the obtained results. The results of this study could lead to the implementation of a routine monitoring programme for nuclear medicine workers.

Participation in EURADOS activities related to internal dosimetry

J. Bento, P. Teles

Regarding the application of voxel phantoms in Monte Carlo simulations, expertise was acquired with the Group's participation in an EURADOS (WG-6 and WG-7) intercomparison exercise. This exercise involved the implementation of a voxel thoracic phantom, where the lungs were contaminated with enriched Uranium. The aim of the intercomparison was to simulate the response of a four HP-Germanium detector array to the several photopeaks emitted by the contaminated lungs. This activity involved the participation in the experimental measurements at the CIEMAT (Spain) and a two month internship at the IRSN (France), the two main institutions involved in this intercomparison. ITN's results were later compared with experimental data and were considered "accepted". To be noted also that ITN was the only institution to use the PENELOPE Monte Carlo program in the simulations.



EURADOS Working Group 2: Harmonization of individual monitoring in Europe

J.G. Alves, P. Ambrosi¹, D. Bartlett², L. Currivan³, J.W. van Dijk⁴, E. Fantuzzi⁵, V. Kamenopoulou⁶, A. McWhan⁷, M. Figel⁸, T. Grimbergen⁹, A. Romero¹⁰, H. Stadtmann¹¹

The aim of this project is to disseminate previous activity carried out by EU-Trimer and the organization of regular intercomparison exercises groups, as well as to identify new activities for EURADOS WG2. WG2 collaborated in the organization of IM2010-European Conference on Individual Monitoring of Ionizing Radiation (347 registrations, 300 communications) being part of the scientific committee, chairing sessions and the refereeing process throughout 2010.

At IM2010 the document *Radiation Protection n. 160* authored by the EU-Trimer group and published by the European Commission was officially presented. Invited talks on the new technical recommendations and on the intercomparison exercises IC2008 and IC2009 were proffered at this conference as well as at the Solid State Dosimetry Conference held in Sydney in September. Talks on Radiation Protection 160 were also given at the ESOREX Symposium and at the RER/9/097 AIEA meeting in Vienna, both held in June.

The IC2009 on extremity dosimeters for photon and beta radiation fields was completed and the certificates presented to participants. IC2010 on whole-body dosimeters for photon fields was carried out and will end in February 2011.

¹ PTB, Germany; ² formerly HPA, United Kingdom; ³ RPII, Ireland; ⁴ formerly NRG, Netherlands; ⁵ ENEA, Italy; ⁶ GAEC, Greece; ⁷ Babcock, UK; ⁸ HZM, Germany; ⁹ NRG, Netherlands; ¹⁰ CIEMAT, Spain; ¹¹ Seibersdorf Laboratories, Austria.

Medical staff and patient dose assessment studies

J.G. Alves, M.F. Pereira¹, A.D. Oliveira, J.V. Cardoso, L.M. Santos, L.C. Freire², A. Pascoal³, J.M. Santos⁴, S. Sarmento⁴

The main objective of this line of activity is to carry out occupational and patient dose assessment studies in specific medical applications. ITN is partner in two research projects funded by *Fundação para a Ciência e a Tecnologia* (FCT) prepared under the framework of collaborations with *Universidade Católica Portuguesa* (PTDC/SAU-BEB/100745/2008 for mammography) and *Instituto Português de Oncologia do Porto* (PTDC/SAU-ENB/115792/2009 for fluoro-CT guided interventional procedures).

In the case of fluoro-CT guided procedures for lung biopsy collection the interventional radiologist is likely to be exposed to higher dose levels, particularly to the hands, upper and lower limbs. The dose assessment methodology was setup and gradually improved so that per-procedure results could be obtained. Ten previously characterized whole-body dosimeters as well as 11 extremity dosimeters inserted in casings in a special designed glove were used to estimate per-procedure dose distributions. Preliminary results were presented as communications (oral and a poster) at the IM2010-European Conference on Individual Monitoring of Ionizing Radiation and the corresponding papers were prepared and published in a journal. This work was considered of interest to the EURADOS Working Group 12 on European Medical Alara Network and is in progress.

¹ ITN Grant holder, PhD student; ² Escola Superior de Tecnologia da Saúde de Lisboa; ³ Universidade Católica Portuguesa, Faculdade de Engenharia; ⁴ Instituto Português de Oncologia do Porto, Grupo de Física Médica.

Characterization of Occupational Exposure in Portugal in the period 2000 to 2008

J.G. Alves, M.B. Martins¹

The aim of this work is the characterization of occupational exposure in Portugal in the period 2000 to 2008. Decree-Laws n. 165/2002, n. 167/2002 and n. 222/2008 entrust to ITN: (i) the creation and maintenance of a Central Dose Register (CDR) where the occupational exposure data of workers in Portugal are stored; and (ii) the publication of annual reports on the statistical analysis of data allowing the characterization of occupational exposure in the country.

The stored data consists of the identity of the worker, affiliation, periodic external dose evaluations in terms of the operational quantities $H_p(10)$ and $H_p(0.07)$ and the on information relative to the worker's facility field of activity and work practices. The facilities are organized in four fields of activity, namely conventional industry (12-13%), medicine (80-85%), research (3-7%) and mining (0-1%). Within each field of activity the ESOREX practice codes were used in the analysis and for international comparison.

The annual effective doses for the 2000 – 2008 period were analyzed, organized in three independent reports corresponding to 2000-2006, 2007 and 2008 and published by ITN. The analysis consisted in the distribution of the number of workers organized by dose intervals, on the determination of the annual average dose for the total monitored population and for the exposed workers, as well as on the calculation of the annual collective dose. The same parameters were also determined for each field of activity and for the ESOREX practices in each field of activity. Electronic versions of the reports are available from ITN's web page.

¹ Retired in October 2009

Monte Carlo simulations of a new micromultileaf collimator (MLC) High Definition 120 (HD120) implemented in a linac used in Radiotherapy

C. Borges^{1,2,3}, N. Teixeira^{2,4}, P. Vaz

After implementation and validation of the linear accelerator head of a Trilogy[®], Varian[®] linear accelerator, up to the jaws, modeling of the brand new micro multileaf collimator HD120 was necessary.

The BEAMnrc[®] code was used to simulate this collimator. For implementation, the density and abutting gap of the MLC had to be determined.

Validations of the implementation were performed using ionometric (lateral and depth doses profiles) and photographic dosimetry (in a solid water phantom) of several open and irregular fields shaped by the MLC.

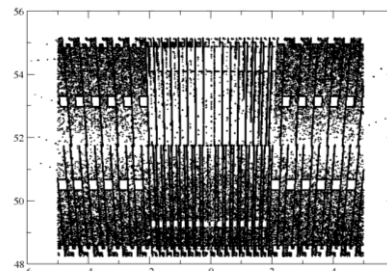


Fig 1 Ray tracing of the HD120 MLC simulated using the BEAMnrc code.

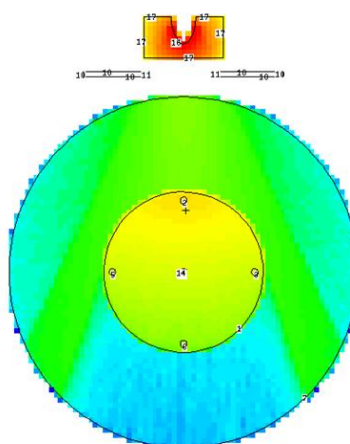
¹Medicalconsult, SA; ²Fac. of Medical Sciences, UNL; ³UPSR; ⁴Escola Superior de Tecnologia da Saúde de Lisboa

Measurements and calculation, using Monte Carlo simulations, of the doses in Computed Tomography (CT) exams

C. S. Figueira, R. Sarmiento, P. Madeira¹, P. Vaz

The objectives of the work consisted in the modeling and simulation, using Monte Carlo methods, of a CT scanner and the associated irradiation conditions, namely the resulting radiation doses. In order to achieve these objectives, measurements using an appropriate phantom and associated radiation detection equipment were performed using a CT scanner in operation at an hospital, to validate the results obtained by Monte Carlo simulations. Some of the crucial modeling issues are the exact knowledge and accurate description of the geometry and constituent materials of the scanner gantry and multiple components (filters and collimators), the knowledge of the energy spectrum of the emitted X-radiation and the electron-to-X-ray conversion efficiency in the anode. In the almost complete absence of information provided by the equipment manufacturer, the uncertainties associated to the geometry, materials and radiation beam, translate into uncertainties affecting the Monte Carlo simulation results. In order to minimize discrepancies between computational (C) and experimental (E) results, sensitivity analysis studies were performed, varying some of the geometric parameters of the components. Using the trial-and-error method to iterate the geometry of one of the main components, it was possible to achieve an agreement between C and E results with less than 5% difference.

The dose distribution computed using Monte Carlo simulations, in the different components of the gantry, with a CT phantom in its center and the bowtie filter and collimators (outside the external circle) is displayed in the Figure.

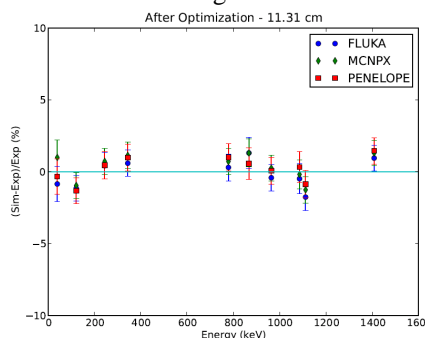


¹Serviço de Imagiologia, Centro Hospitalar Lisboa Central – Hospital de São José.

Modelling and understanding the behaviour of HPGe detectors

R. Luís, J. Bento, P. Nogueira, G. Carvalhal, L. Silva, M. Reis, P. Teles, P. Vaz

The existing competence in Monte Carlo simulations was deployed to address modelling issues of radiation detectors. A transversal activity involving the Measurement Laboratory (LM) and the Dosimetry and Radiobiology Group (GDR) was pursued, in order to gain further insight in the response of HPGe detectors (experimental and simulated detection efficiencies are shown in the picture), namely in the efficiency calibration and coincidence summing corrections, among others. Three different state-of-the-art Monte Carlo codes were used, namely FLUKA, MCNPX and PENELOPE. Of these activities resulted 1 article published in NIM A and a presentation at the most important international Conference on Monte Carlo methods applied to radiation physics and particle transport simulation (MC2010).



Optimization studies of the ISOLDE targets, at CERN

R. Luís, T. Stora¹, P. Vaz

The ISOLDE facility at CERN has been one of the premier radioactive ion beam facilities worldwide since it started operating in 1967. In the studied configuration, a 1.4 GeV pulsed proton beam hits a tungsten spallation target, generating intense neutron fluxes that induce fission in a UCx target. The first objective of this work was to predict the yields of neutron-rich isotopes of Zinc and Cadmium using the Monte Carlo code FLUKA. After validation with the experimental yields obtained at ISOLDE, an optimization of the targets configuration was undertaken, in order to reduce the contamination of the desired neutron-rich isotopes by proton-rich isobars. The Figure shows the improvement predicted for the contamination of Zinc isotopes by Rubidium isobars. For ⁸⁰Zn, an important nuclide for the Physics program at ISOLDE, there is an improvement in the ratio ⁸⁰Zn/⁸⁰Rb of the order of 20. A similar result was obtained for the ¹³⁰Cd/¹³⁰Cs ratio.

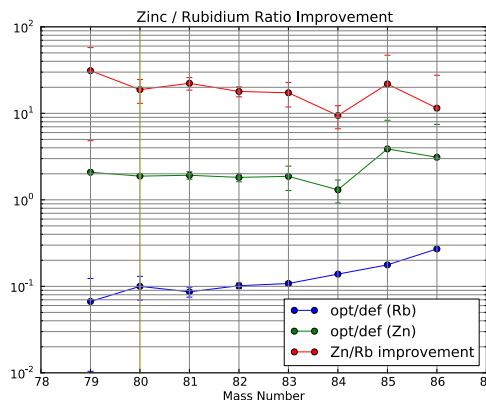


Fig 1 Zn / Rb ratio improvement.

¹ CERN-ISOLDE

Computational Dosimetry – Radiation Protection, Dosimetry and Shielding studies for the HIE-ISOLDE facility at CERN

Y. Romanets¹, V. Vlachoudis², AP. Bernardes², Y. Kadi², P. Vaz¹

The High Intensity and Energy ISOLDE (HIE-ISOLDE) project is an upgrade of the existing ISOLDE facility, at CERN. After upgrade it is expected to raise the operational energy of the proton beam up to 2 GeV and intensity up to 4 μA. An increasing of the nominal parameters of the operation of the facility requires validation of existing geometry and shielding of the installation from the radioprotection and radiation safety point of view. The detailed study of the dose distribution (shown in the Figure), particle fluxes and activation calculation was performed in order to assess the radiation safety and radioprotection of the upgraded facility. On this work the state-of-the-art FLUKA Monte Carlo code was used.

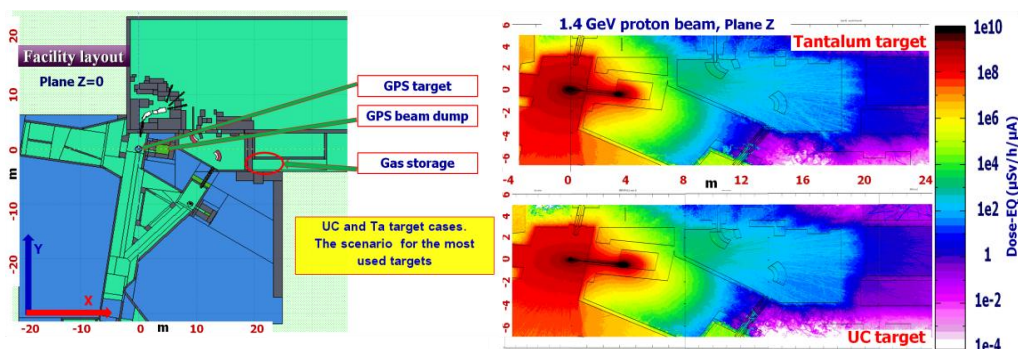


Fig 1 Layout of the ISOLDE facility (left) and Dose-Equivalent distribution for different spallation targets

¹ CERN-ISOLDE

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

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

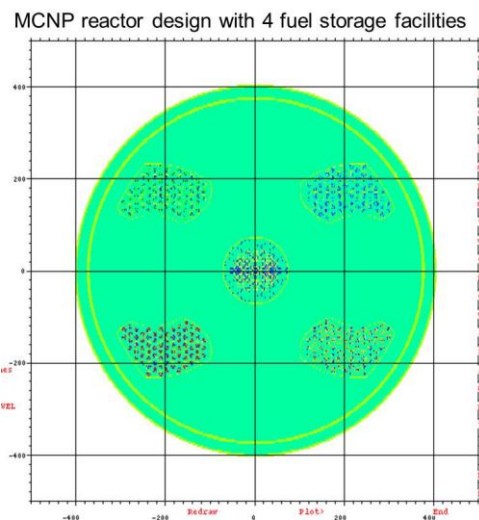
IP EUROTRANS is a European Union co-financed project (ref. FI6W-CT-2004-516520) in the 6th Framework Program EURATOM. The objective of IP EUROTRANS is the design and the feasibility assessment of an industrial ADS (Accelerator Driven System) prototype dedicated to the transmutation of high-radiotoxicity and long-lived radioactive waste. During 2010, the Portuguese team, 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”). 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).

¹ Fac. de Engenharia / Univ. Católica Portuguesa

Central Design Team (CDT) for a Fast-Spectrum Transmutation Experimental Facility

S.Di Maria, P.Teles, P.Vaz

The project CDT is a European Union co-financed Collaborative Project in the 7th Framework Program EURATOM (Grant agreement n°: FP7-232527). The project aims to demonstrate an efficient transmutation of high level wastes and associated technology through a system working in subcritical and/or critical mode. The ITN team participates in the Work Package 2 entitled “Design of the Fast Spectrum Transmutation Experimental Facility (FASTEF) in sub critical and critical mode”. In particular ITN is responsible for the neutronic assessment and criticality analysis in the fuel storage facilities both for radioprotection and damage material purposes. The studies undertaken consisted of Monte Carlo simulations using the program MCNPX. In the Figure, the layout of the four storage facilities of the facility is shown with the reactor core in the centrum.



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 for 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 Package 3 entitled “Define requirements for RPO competencies and establish European guidance for RPO training”, Work Package 4 entitled “Establish the reference standards for RPE training”, Work Package 5 entitled “Develop and apply mechanisms for the evaluation of training material, events and providers”, Work Package 8 entitled “Organise pilot sessions, test proposed methodologies and monitor the training scheme effectiveness”, Work Package 10 entitled “Collaboration for building new innovative generations of specialists in radiation protection”

Participation of ITN in the n-TOF-Ph2 experiment (PS213) at CERNI.F. Gonçalves¹, P. Vaz, C. Cruz¹, J. Neves¹, C. Carrapiço², R. Sarmiento², L. Ferreira¹, L. Távora³

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

These cross-sections measurements are required in many applications such as the design of innovative Accelerator Driven Systems (ADS) for incineration of nuclear waste and energy production, radioisotope production for medical and industrial applications and many other subjects in Astrophysics, Nuclear Physics and Nuclear Technology. New or improved measurements of neutron cross-sections will also be very valuable for Radiation Shielding, Dosimetry and Monte Carlo Radiation Transport calculations. During 2010, the ITN team members in cooperation with researchers from CEA/Saclay and INFN/Bari, participated in: the analysis of the ²³³U neutron capture data sets, the analysis of the ²³⁶U neutron induced fission data sets, 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 IST / Physics Department² FCT Ph.D. student³ C. de Instrumentação / U. Coimbra**SERVICES****Individual and Environmental monitoring performed by ITN’s individual monitoring service**J.G. Alves, M. Martins¹, M.F. Pereira², S. Rangel, M. Saraiva

The Individual Monitoring Service (IMS) for external exposure at ITN is based on a TLD system that consists of two 6600 Harshaw readers and on the whole body dosimeter Harshaw 8814 TL card and holder containing two LiF:Mg,Ti (TLD-100) elements for the evaluation of $H_p(10)$ and $H_p(0.07)$. In 2010, approximately 2,700 workers were monitored on a monthly basis. Following ITN’s application to IPAC-*Instituto Português de Acreditação* for the accreditation of its laboratories according to the EN ISO/IEC 17025 standard, two technical audits took place at the IMS in 2010. The first one was performed by ISQ-*Instituto de Soldadura e Qualidade* and the second one by an IAEA-International Atomic Energy Agency appointed expert under project RER/0/021.

As a result of the overall production of the service directed for customers but also as support to research projects a total of five communications were presented at the IM2010-European Conference on Individual Monitoring of Ionizing Radiation. The laboratory took also part in the EURADOS 2010 Intercomparison of whole body dosimeters for photon fields.

Environmental monitoring for the assessment of the ambient dose equivalent $H^*(10)$ is performed at four sites at ITN *campus* (three evaluations per quarter) and at nine sites spread over the country on a quarterly basis. The results are used to compute the annual average dose equivalent rates for the monitored sites and are published in the National Radiological Environmental Monitoring programme annual report.

¹ Retired since 30th November; ² ITN Grant holder, PhD student.

Risk and Safety Assessment

A.D. Oliveira, T. Antunes, A. Baptista, Y. Romanets, L. Portugal, R. Trindade, P. Vaz

At the end of 2009 it was introduced the “Document for the Safety Culture” (DCS) which suffer major improvements due to the collaborations of the staff of hospitals and clinics responding to the request of ITN for their active participation. The DCS is an ITN document, based in IAEA recommendations, European Directives and Portuguese legislation. Related with the DCS, it was introduced two important tools of safety assessment: a) a radiation protection program checklist and b) a radiation protection responsibilities checklist. The “responsibility checklist” aims to promote a higher level of commitment from hospital management bodies in what concerns safety culture, regular inside safety assessment and learning from experience. Several hospitals deserve a special mention due their very good commitment with the DCS, in arbitrary order: a) CIMC-Instituto CUF, Medicina Nuclear, Porto (DCS n°3/2010); b) Diaton, Medicina Nuclear, Viseu (DCS n°4/2010); and c) Hospital da Luz, Braquiterapia, Lisboa (DCS n°12/2010). One of the main problems founded was concerned with the responsibility structure and a lack of well-defined internal radiation protection rules. Several, radiotherapy, nuclear medicine and brachytherapy facilities are at the moment working in their DCS documents.

Another important activity, during 2010, in radiological assessment and training was developed in the CPLP countries Mozambique and Cape Verde, where 8 cargo container scanner facilities using LINACS were assessed from the point of view of radiation safety.



Radioprotection and Radioactive Waste

Romão Trindade

The Radioprotection and Radioactive Waste Group (GRRR) has pursued its involvement in KADRWASTE (FCT), ACSPET (FP7) and PETRUS II (FP7) projects.

Concerning Education & Training, 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 **13** Advanced and Post-Graduation Studies (DFA, Master) at IST, FCUL and ESTSL in the field of radiological protection, radioactive waste management, transport of radioactive materials and radiological emergencies. They have also participated in **9** professional training courses on radiological protection and safety, 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.

Considering the activities related to legal obligations such as licensing of sealed sources for medical, industrial, teaching and research applications the Group has issued **440** licensing requested for analysis and authorization during 2010. This year, **555** gamma spectrometry analysis for research, radiological protection and monitoring purposes were carried out in the Radioactive Samples Measurement Laboratory (LMAA/GRRR).

Also during the last year and still considering legal obligations, **186** requests for collecting and storing radioactive waste, from medical, industrial and

research applications, were received and processed. To do this work GRRR has only one person.

ITN's radioactive wastes discharges compliance with Artº 35º of Euratom Treaty recommendations was pursued in 2010 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 and the application of the Best Available Technology (BAT).

The *Campus* environmental gamma radiation dose continued to be assessed through the gamma monitoring network, GAMMANET, and the data reported in compliance of Artº 35 of Euratom Treaty.

Detection of radioactive materials in scrap metal is still continued as happening in other EU MS and this year **8** events were reported to ITN.

Radiological surveillance was carried out by GRRR during the stay of **5** military nuclear vessels in the Lisboa Harbour and also **10** verifications and monitoring on radiological facilities and equipment.

The Monitoring Programme of the radioactive liquid discharges into the public sewage of Lisbon as well as the monitoring of the four ETAR'S (waste water treatment facilities) was continued in 2010, in collaboration with Lisboa Council Borough and public and private nuclear medicine facilities

During 2010, GRRR has organized **4** Workshops and Meetings.

In 2010, were published **15** internal reports related to the activities carry out by the GRRR.

Research Team

Researchers

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

Fellow

A. BAPTISTA

Technical Personnel

L.M. PORTUGAL
J. VENÂNCIO

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

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

The project (PTDC/CTE-GEX/82678/2006) has pursued in 2010 with the continuation of its tasks and the beginning of the submission and publication of the first papers related to it. The data concerned the radiometric surveys obtained from *in-situ* gamma spectrometry with NaI (TI) 3''x 3'' e 5''x 5'' probes was analyzed in terms of the geological settings. Safety assessment of low and intermediate level waste repositories requires the understanding of radionuclides sorption-desorption mechanisms, mainly the degree of interaction between radionuclides and mineral surfaces. Among the different radionuclides that are part of the Portuguese radwastes' inventory ¹³⁷Cs is one of the most important from the radiological point of view due to its high radiotoxicity. The adsorption studies using ¹³⁷Cs and the characterization of geomaterial samples (soils and *rañas*) collected in the framework of the KADRWaste project, using both Instrumental Neutron Activation Analysis (INAA) and gamma spectrometry for chemical elemental composition and radionuclides content respectively have been pursued. The geomaterial samples that were collected were of two kinds: soils, that are basically peridotites and gabbros and are part of the Iberian Hercynian Massif located in most of the Western half of the Iberian Peninsula, and *rañas* that are sedimentary deposits originated from the same area. The clay components of natural geomaterials named *rañas*, has been studied for their potential as effective liner/backfilling/buffer barriers for Low and Intermediate Level Wastes (LILW) repositories. Characterization of geomaterials and the capacity adsorption of the *rañas* have also been carried out by using two different but complementary techniques: *k₀*-based Instrumental Neutron Activation Analysis and Gamma Spectrometry Methods. Batch mode experiments studies related to the adsorption/desorption of different ¹³⁷Cs concentrations at different pH values and flow rate for different *rañas* samples were supposed to be carried out at ITN with Teflon continuous flux reactors. These were constructed at ITN workshop according to a FCUL model and expected to be used at ITN, FCUL and FCUP for adsorption/desorption studies of radioactive and non-radioactive elements in solutions containing clay minerals. Samples were

analysed by the THERMO ICP-MS existent at Environmental Agency at the market price.

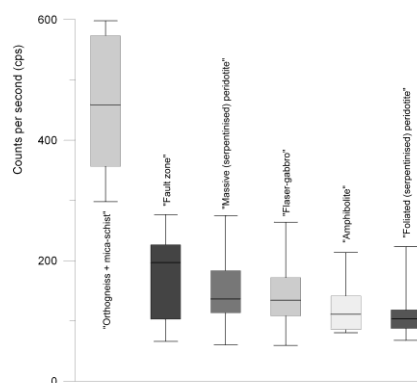


Fig- Box-whisker diagrams of the main distributions of gamma-ray values assigned to the "lithological" and "structural" sub-groups for the Morais area.

¹(FFC/Geology/Creminer/FC/UL);

²(ADFC/Geology/FC/UP); ³(U. Évora)

Published work

E. Andrade, M.J. Madruga, I. Bobos, I. Paiva, F. Maia, A. Mateus, R. Trindade, M.C. Freitas, M.A. Gonçalves. Characterization of Portuguese geomaterials, the clay component of *rañas*, as potential liners for low and intermediate radioactive disposal sites. *J. Radioanalytical & Nuclear Chemistry*, (2010) 286:777-783.

M. Reis, M.C. Freitas, A. Mateus, I. Paiva, L. Silva, I. Dionisio, H.M. Dung, M.J. Madruga, P. Duarte, M.A. Gonçalves. *Characterization of Geomaterials from NE Portugal using Instrumental Neutron Activation Analysis (INAA) and Gamma Spectrometry*, Fourth International Symposium on Nuclear Analytical Chemistry (NAC-IV), Bhabha Atomic Research Centre, Mumbai, India, 15-19 November 2010 (Poster).

ACSEPT-Actinide reCycling by SEParation and Transmutation (7th Programme EURATOM- FP7-Fission 2007)*I. Paiva, J. Marçalo, C. Lourenço, R. Trindade, P. Vaz*

ITN (UPSR/GRRR/GDR and UCQR/QIO) organized the Second Annual ACSEPT Project Meeting, the First ACSEPT International Workshop on *Innovative Solutions for Sustainable Nuclear Energy* in collaboration with EURATOM FP7, CEA, IAEA, ENS and the First Meeting on *Pyro-Metallurgy*, with Russia, in a total of 120 participants. Speakers from Khlopin and RRC-KI, Russia; IGCAR, India; WSU and INL, USA; CEA and ANDRA, France; PSI, Switzerland; Titech, Japan; KTH, Sweden; CEA and ANDRA, France and SKB, Sweden were invited to participate in the workshop. ITN's five progress reports were already presented in Domain 1, WP1.2, M 1.2.2, M1.2.4, D1.2.1. A new ligand (C5-BTBP) from CEA was delivered to ITN to carry out studies on gas-phase reactions of Ln(III) and An(III) using FTICR/MS. Complexation studies of C5-BTBP with $GdCl_2^{2+}$ and $CmCl_2^{2+}$, where formation of $MCl_2(C5-BTBP)^+$ ions was observed but kinetics of association could not be measured due to the low volatility of C5-BTBP. ITN also reported the experimental study, by FTICR/MS, of the association reactions of MCl_2^+ ($M = Cm$ and Gd) with pyridine, a building block of the C5-BTBP ligand. Related studies were performed by ESI-QIT/MS to probe the relative affinity of several N-donor bases (building blocks of the ACSEPT ligands), in solution and in the gas phase, towards several LnX_2^+ ions ($X = NO_3, Cl$). The ACSEPT grantee has been to Marcoule on a short visit to prepare for an experimental visit of 2 months working at ATALANTE Facility, being supported by the ACTINET-I3 Network where UCQR/QIO has now a project in collaboration with CEA-ATALANTE and LBNL/USA.

PETRUS II—Towards an European training market and professional qualification in Geological Disposal*I. Paiva, P. Vaz, R. Trindade.*

PETRUS II has pursuing activities to identifying existing EU training and education actions in radioactive waste management/geological disposal E&T and setting-up the recognition of European training programs on geological disposal. Audiovisual and in-house Pilot E&T sessions, shared by different partners, have already been in place. In 2010, the First Annual PETRUS II Meeting was organized by ITN. Ten international organizations, including independent regulatory bodies, representatives of ECFP7 and ENEN, were present in a total of almost 40 participants. PETRUS II results have shown the importance of end-users, courses' providers and EU experts working together to develop and sustain a qualified, mobile workforce with transferable skills that will allow career progression in the newly strategic rebirth of the nuclear industry. Also it will produce future skilled technical and scientific experts. Priority Activities to support a lifelong learning system, increasing mobility of European learners and flexibility of learning pathways to achieve the required qualifications using the *European Credit system for Vocational Education and Training* (ECVET), are being launched. PETRUS II members will also extending their input to the ECNET project to reinforce collaboration with China.

Characterization of Suitable Areas for a Long-Term Radioactive Waste Repository Facility in Portugal*P. Duarte¹, I. Paiva, A. Mateus², R. Trindade*

The Ph.D. work supervised by FCUL and ITN, related to some of the tasks of the FCT project KADRWaste has suffered several corrections and setbacks within the last year. There were many reasons for that including the leaving of the Ph.D student, without completing all the tasks of 2010. Despite this setback, a paper was produced and accepted for publication due to the efforts of both Institutions. During this year, there was collaboration with National Research Center of Materials Science, Borj Cedria Technopark, Tunisia, through FCUL/Geological Department. Portuguese soil and clay samples prepared by FCUL and ITN were sent to Tunisia to carry out adsorption/desorption experiments with different metals to compare results with the Tunisian samples. Further cooperation with Tunisia Group and with FCUL, it is envisaged through a Tunisian Pos-Doc student.

¹ Left ITN in December 2009² Dep. Geologia, FCUL.**Radioactive Liquid Discharges from Hospitals in Public Sewage of Lisboa Borough Council (CML)***R. Trindade, I. Paiva, L. Portugal, A. Baptista, J. Venâncio, F. Gomes, L. Silva, M. Reis*

Radioactive liquid discharges from public and private nuclear medicine facilities in Lisbon public sewage as well as residual effluents from Lisboa four Water Treatment Plants (ETARs) have been monitored by UPSR/ITN in 2010. The Project was divided in 4 different programmes related to the sites where the samples were collected. Programme I involved sequential collection of discrete samples in sampling points from nuclear medicine facilities. In Programme II, discrete samples were taken at one single discharge point of each Lisboa's ETARs. The Programme III has involved the affluent to ETAR's and their effluents. Finally, the Programme IV was related to sewage of the municipality neighbours of Lisboa. Sampling was carried out in order to identify the radionuclides present and their activities. About 254 samples of liquid effluents were collected and analysed by quantitative and qualitative gamma spectrometry. During this year there were no changes to this Project that has been collaboration with the Lisbon Borough Council.

SERVICES

1. Radioactive waste management

During 2010, **186** requests for radioactive waste collection were received, collected, segregated, and transported for the interim storage facility “Pavilhão de Armazenamento Interino de Resíduos Radioactivos”, (PAIRR) at ITN *Campus*. Concerning radwaste, it is very important and urgent to define and to establish a national plan related to radioactive wastes produced in Portugal. In the last years only one technician is working at PAIRR, which is not enough to carry out all duties.

2. Sealed sources licensing

According Decree-Law n° 38/2007 and Decree-Law n° 165/2002, **440** sealed sources licensing were issued: national territory introduction licences (**128**), transfer licences (**60**), transport licences (**89**) and ownership licences (**163**). Only one person is related with this activity. It was developed a data base for radioactive sealed sources.

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

The environmental dose gamma radiation at ITN *Campus* is continuously being measured by the gamma network, GAMMANET. The data are collected, analysed and reported to the EU, according to articles 35° and 36° of the Euratom Treaty and also to the National Report “Programas de Monitorização Radiológica Ambiental”.

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

Radioactive liquid wastes originated at ITN are analysed and measured at “Estação de Controlo das Descargas dos Efluentes Líquidos Radioactivos” (ECoDELiR) before being discharged into Estação de Águas Residuais (ETAR). The data are reported to the EU according Articles 35° and 36° of Euratom Treaty and to the Radioactive Substances Committee of OSPAR Convention and also to the National Report “Programas de Monitorização Radiológica Ambiental”. In 2010 the work to repair and to improve ECoDELiR was pursued.

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

In 2010 and as requested by IPO-CROC, EPE, Coimbra, the radiological survey of radioactive liquid effluents from the IPO’s Medicine Nuclear Retention Tanks, was carried out by the Group before discharge into the public sewage.

6. Nuclear vessels radiological monitoring

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 when nuclear vessels reach the Portuguese harbours. This year, **5** nuclear vessels stayed at Portinho da Costa harbour and estuary of Rio Tejo. The reports were sent to Ministry of Defence.

7. Radioactivity in scrap metal

In 2010, and as result of radiological surveys requested by the smelting industry, **8** events related to the detection of radioactive materials in scrap metal at melting factories have been reported. The material collected has been stored at Pavilhão de Armazenamento Interino de Resíduos Radioactivos, (PAIRR) as radioactive waste. Reports were sent to the smelting company.

8. Radiological protection and safety verifications and monitoring

During 2010, GRRR has carry out **555** gamma spectrometry analysis and **10** verifications and monitoring concerning radiological protection and safety purposes at medical and industrial facilities and also to research projects.