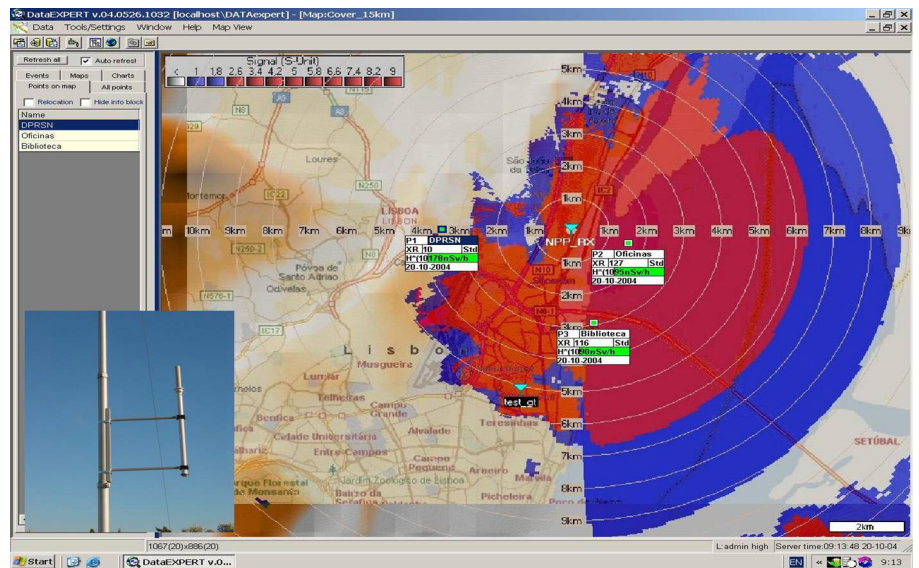


**Department of Radiological Protection
and Nuclear Safety**



Department of Radiological Protection and Nuclear Safety

C. Oliveira

The main activities developed in 2005, in the Department of Radiological Protection and Nuclear Safety are organized in order to comply with the national and international duties attributed to ITN, to perform services to the community, research and teaching activities, and to answer the technical and scientific solicitations in the radiological protection field. Participation in international and national commissions continues to have a significant importance in the Department activities.

At National level the multi-institutions project-MinUrar has been completed by the end of 2005. At international level, the EUROTRANS- Design and study of the technical feasibility of ADS for the transmutation of radioactive waste -must be referred as one of the 6th Framework Programme projects started at ITN in 2005.

The LMRI- Lab. Metrology of Ionizing Radiations participates in an international process leading to the mutual recognition of national measurements standards of calibration and measurement certificates issued by the national metrology laboratories that is still being implemented among the Metre Convention Member States. The LMRI Calibration and Measurements Capabilities were published in the BIPM database.

Activities concerning the environmental radioactivity monitoring are centralized in the Radiological Environmental Monitoring Programme. Efforts to fit the recommendations of the EU's verification mission to comply with Article 35 of Euratom Treaty pursued including the implementation of an environmental database.

At the beginning of the year, a Measurement Unit was created. Main efforts were the adoption of measures to implement the ISO/IEC 17025 requirements including the introduction of a modern Laboratory Information Management System. All these efforts are part of the coordinate action for laboratory accreditation.

Also to comply with Article 35, a gamma monitoring network to measure radiation due to abnormal discharges in the environment and new monitoring equipment to more efficiently monitoring the radioactive liquid discharges of the campus into the public sewer have been installed.

During this year, the Central Dose Registry, complying with activities attributed by law to ITN, started the process for the collection of dose data measured and reported by the dosimetry companies operating in Portugal.

Reports for the General Directorate for Health to issue licences have been assured by DPRSN within the framework of the safety assessment activities of the Department.

Establishment of the infrastructure and installation support services for the Radionuclide Particulate Station belonging to the International Monitoring System at S. Miguel (Açores Islands), in the framework of the CTBT (Comprehensive Nuclear Test Ban-Treaty) has started during last year.

The DPRSN has been involved in the promotion and implementation of a radiation protection structure within the ITN *Campus* according to the international recommendations.

Education and training courses for professional workers are being provided. In order to fulfil a lack in Radiological Protection education at University level, a Master Course on Safety and Radiation Protection starting from an initiative of DPRSN and in collaboration with the Lisbon Technical University (IST) is in progress. Students from DPRSN participate in this Master. There is also a collaboration of DPRSN with FCL/Chemistry/ITN on the Master Course Biomedical Inorganic Chemistry. DPRSN' staff is also a regular collaborator on several Courses organized by the University and Health Technical Schools.

DPRSN Staff

Researchers

C. OLIVEIRA, Princ.
F.P. CARVALHO, Princ.
J.P. VAZ, Princ.
M.A. NEVES, Princ.
M.B. MARTINS, Princ.
M.J. MADRUGA, Princ.
A.D. OLIVEIRA, Aux.
E.M.M. AMARAL, Aux.
J. ALVES, Aux. I. Paiva, Aux.
M. REIS, Aux.
N. PINHÃO, Aux. (80%)
O. GIL, Aux.
R. TRINDADE, Aux.
J.A. CORISCO, Assistant

Administrative and Technical Personnel

J. CARDOSO
L.M. PORTUGAL
T. ANTUNES
G.L. SILVA
A.M. ROSA
D. ALVES
E.F. GONÇALVES
J. OLIVEIRA
J. SEBASTIÃO
J. VENÂNCIO
L. SANTOS
M.A. LIBÂNIO
M.M. SEQUEIRA
M.E. PACHECO
M.A. JORDÃO
V. CORDEIRO

Dose Assessment and Dose Registry

João Garcia Alves

The activity of the Dose Assessment and Dose Registry unit is directed towards the assessment of doses to the Portuguese population due to several types of exposure to external radiation.

The activities developed in 2005 were mainly concentrated on the performance of the individual monitoring service of ITN in the fields of individual and environmental monitoring.

In 2005 the main activities developed and improved at this Unit were focused on:

Assessment of the occupational radiation doses:

The Individual Monitoring Service (IMS) of ITN provided individual monitoring for external exposure to approximately 3,000 workers in Portugal, with a monitoring system based on thermoluminescence dosimetry (TLD).

Strong staff reduction was observed at the IMS with only one single replacement.

Improvements to the Central Dose Registry and analysis of the occupational exposure data:

In 2005 the CDR started the process for the collection of dose data measured and reported by the dosimetry companies operating in Portugal.

At presently, the CDR contains all the occupational exposure data concerning the period 1957 to 2004.

The analysis of the occupational exposure data is also one of the aims of this work.

Improvements to the quality control program: The reduction of staff observed in 2005 hindered the analysis and improvements in quality control that would be envisaged under normal circumstances.

A database for the storage and analysis of important quality control parameters was created and presented at the Individual Monitoring Conference held in April.

The application for Accreditation according to the ISO 17025 Standard, due to take place in 2005, was not attained due to the above mentioned reasons.

Assessment of the cosmic radiation dose received by aircrew:

As a result of an on-going collaboration with the Serviço de Ginecologia e Obstetrícia of the Hospital da Força Aérea Portuguesa, the in-flight cosmic radiation doses received by aircrew in military transport flights was estimated using specific software programs.

Assessment of the environmental gamma radiation dose to the Portuguese population:

Environmental monitoring is one of the tasks assigned to ITN by Decree-Law 138/2005 concerning the accomplishment of Article 35 of the Euratom Treaty.

This Unit also collaborated to the MinUrar project performing the evaluation of the natural gamma radiation dose.

On-going collaboration in international working groups was developed in the framework of both EURADOS and ESOREX activities:

Eurados – European Radiation Dosimetry group: Working group 2 of Eurados entitled *Harmonization of Individual Monitoring in Europe* will continue until the end of 2006.

Esorex – European study on occupational exposure: The update of the Portuguese CDR with the occupational exposure data reported by the dosimetry companies other than ITN was of fundamental step for the participation of ITN in this working group.

In 2005 approximately € 167.600,00 were raised due to the operation of the Individual Monitoring Service.

Research Team

Researchers

J.G. ALVES, Aux.
M.B. MARTINS, Princ.
E. AMARAL, Aux. (on sickness leave)

Students

J.N. ABRANTES, Undergraduate
(transferred on 31-Mar-05)
L.C. NOVAIS, Undergraduate FCT-Euratom grant

Technical Personnel

G.C. RANGEL (retired since 31-Mar-05)
C.M. FAVINHA (transferred on 01-Aug-05)
J.V. MONTEIRO (retired since 05-Sep-05)
S. RANGEL
E. FLORES

The Central Dose Registry: Analysis of Occupational Exposure

M.B. Martins, J.G. Alves, J.N. Abrantes¹

Objectives

ITN is entrusted the task to create and maintain a Central Dose Registry, according to Decree-Laws 165 and 167 of July, 2002.

In the beginning of 2005 Central Dose Registry (CDR) contained only the occupational exposure data of the workers monitored in Portugal by ITN-DPRSN since 1957 to 2004.

It was the aim of the CDR for 2005 to start the insertion of the data evaluated by other monitoring services external to ITN.

Results

The CDR gathers the information relative to the monitored workers and to the facilities that requested monitoring, grouped into four different fields of activity, namely health or medicine, conventional industry, research and mining. In each field of activity the most frequently found functions and practices were defined.

Full compatibility of the CDR and the databases used for routine monitoring at ITN had already been achieved in 2004.

In 2005 the CDR started the process of occupational dose data collection from monitoring companies operating in Portugal other than ITN.

The main aim was concentrated on the collection and insertion of the annual dose data for the period 1997-2004. In 2005, approximately 40,950 accumulated doses were inserted.

A questionnaire was prepared by the CDR and made available to the monitoring companies in order to obtain the necessary information concerning the workers, practices and doses in a compatible format.

Meetings were held with all the companies' representatives and with the *Centro de Protecção contra os Riscos Profissionais*.

The CDR was registered at the *Comissão Nacional de Protecção de Dados*. At present all the annual dose data evaluated in Portugal in the period 1997 to 2004 have been inserted in the CDR. The CDR presently contains the records of approximately 35,300 workers from 2,108 facilities monitored by the five monitoring companies operating in Portugal.

The statistical analysis of data is also a task entrusted to ITN by Law, as mentioned above.

The CDR also allows the statistical analysis of the occupational exposure data stored. The number of monitored workers and facilities can be grouped by fields of activity, their respective distribution by effective dose intervals can be calculated, as well as the corresponding average and collective doses. These parameters are important to characterize the occupational exposure in Portugal.

In 2005, based on the data of the RCD, a study was carried out with workers of Nuclear Medicine. This was one of the aims of the work presented at the IM2005 – Individual Monitoring of ionizing Radiation held in Vienna.

Published or in press work

1. M.B. Martins, J.G. Alves, J.N. Abrantes, A.R. Roda Occupational Exposure in Nuclear Medicine in Portugal in the 1999 - 2003 Period, *IM2005 – European Workshop on Individual Monitoring of Ionizing Radiation*, Vienna, Austria 11-15 April (2005), *Radiat. Prot. Dosim*, in press.

¹. Transferred on March 31st, 2005.

Assessment of the Cosmic Radiation Dose Received by Military Aircrew in Transport Missions*J.G. Alves, J. Mairós¹*

This project aims at performing an estimate of the cosmic radiation dose received by military aircraft crews on realistic transport missions. The cosmic radiation dose received was estimated for transport missions carried out on the Hercules C-130 type of aircraft by a single air squad in one month. The flights departed from Lisboa to areas such as the Azores, to several countries in central and southern Africa, to the eastern coast of the USA and to the Balkans and an estimate of the cosmic radiation dose received on each flight was carried out. A monthly average cosmic radiation dose to the aircrew was determined and the dose values obtained were discussed in relation to the limits established by the European Union Council Directive 96/29/Euratom. The estimates were performed using the EPCARD v3.2 and the CARI-6 computing codes. EPCARD v3.2 was kindly made available by GSF-National Research Centre for Environment and Health, Institute of Radiation Protection (Neuherberg, Germany). CARI-6 (version July 7th, 2004) was downloaded from the web site of the Civil Aerospace Medical Institute, Federal Aviation (USA). Special attention was given to the case of a pregnant crew member.

¹ Hospital da Força Aérea, Serviço de Ginecologia e Obstetrícia, Az. dos Ulmeiros, 1649-050 Lisboa.

Individual Monitoring Service, Improvements to the Quality Control program*J.G. Alves, S. Rangel, E. Flores, L. Novais, J.N. Abrantes¹, G. Rangel², J. Monteiro², C. Favinha³*

The Individual Monitoring Service (IMS) at ITN is based on a TLD dosimetry system, that consists of two 6600 Harshaw TLD readers and on the Harshaw 8814 TL card and holder containing two LiF:Mg,Ti (TLD-100) detectors for the evaluation of Hp(10) and Hp(0.07). In 2005 the IMS provided monitoring for external radiation to 3165 workers from 226 facilities in Portugal. Nearly 85.6% of the monitored persons work for the medical field of application, 8.2 in the conventional industry and 6.2% in research.

A quality control programme has been running at the TLD section of the IMS since 2000. Since then regular evaluation of the quality control parameters have suggested some modifications that were introduced, when necessary. A database for the storage of quality control parameters was created using MS-Access. At the moment, the database has a passive role and is used for storage of data and for the retrospective statistical evaluation of important parameters and their evolution with time. It is regularly fed with the files generated by the NETREMS and/or WINREMS software from Harshaw (presently Thermo Electron Corporation), and allows a quick and user friendly visualization of the data.

¹ Transferred to another Group, ² Retired, ³ Transferred to another institution.

Assessment of the Environmental Gamma Radiation Dose to the Portuguese Population*J.G. Alves, L. Novais, S. Rangel, E. Flores*

Environmental monitoring for environmental gamma radiation is one of the tasks concerning the accomplishment of Article 35 of the Euratom Treaty. Three measurement points were selected at ITN as used as reference points for the setup of the methodology in use. By the end of October a net of measurement points was established.

This Unit also collaborated to the MinUrar project performing the evaluation of the natural gamma radiation dose in regions close to the former Uranium mines.

Environmental Radioactivity

Maria José Madruga

The Environmental Radioactivity group is the only technical body in the country with specialised equipment and trained staff suitable to fulfil the State's national and international obligations in this field (ex. Artº 35 and Artº 36 EURATOM Treaty). Recently, the Law Decree 138/2005 of 17th August affirms this ability. In this context a National Radiological Environmental Monitoring Programme is on going. This programme consists on measuring the natural and artificial radionuclides in: aquatic ecosystems, mainly rivers, whose basins receive effluents from Spanish nuclear power plants (ex. Tejo River), estuaries and portuguese coast; terrestrial environmental radioactivity (foodstuffs, drinking water, soils, etc.) due to the atmospheric fallout or enhanced natural radioactivity and, atmosphere radioactivity (rainwater and aerosols) due to the anthropogenic radionuclides and cosmic radiation.

Current research project are on going to investigate the levels of radioactive contamination in and around the old uranium mining sites in order to assess the radiological risk for the population and to assist with defining priorities for environmental rehabilitation.

Studies concerning the determination of indoor radon concentrations, radon exhalation from building materials and radon mitigation measures are also persued.

The technical services developed by this group are often carried out under contract with companies or, by request from enterprises or Government organizations. Some of these technical services are: the evaluation of the radioactivity levels in public water supplies (Decree-Law nº243/2001) and mineral waters, the radioactivity analyses of foodstuffs, goods and building materials to export, and indoor radon measurements. The group income of these technical services was about 80 000 €.

During this year the group have participated in the elaboration of administrative and technical procedures following the NP EN ISO/IEC 17025 having as main objective the accreditation of global alpha, global beta and tritium measurements techniques. An environmental database was implemented, in which all the internal and external samples, the techniques associated to the analyses, the results and the respective analyses reports are recorded.

In 2005, the group participated in coordination with the DPRSN/Measurement Unit in three international inter-comparison exercises: The first one, organized by the European Commission in the framework of the Artº 35, concerning the determination of ⁴⁰K, ⁹⁰Sr and ¹³⁷Cs in milk powder; the second, organized by the IAEA, for the measurements of anthropogenic and natural radionuclides in mussel samples; and, the third for the determinations of natural and artificial radionuclides in vegetables ashes, organized by the Consejo de Seguridad Nuclear (Spain). The results will be published next year. The results published in 2005 concerning previous exercises were good and in one case were considered excellent.

An important part of the output of the group has been the training of young students. In the framework of the EURATOM/Radiological Environmental Monitoring Programme, five fellows have been awarded with FCT grants.

The main concern of the group is the lack of human resources. To fulfil the State's national and international obligations (Artº 35 and Artº 36 EURATOM Treaty) is absolutely necessary specialized technical personnel. During 2005 three technicians were retired and one is waiting the retirement decision. We sincerely hope that this problem might be solved rapidly.

Research Team

Researchers

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

Students

A. R. GOMES, Graduate, FCT grant
A. S. LEMOS, Graduate, FCT grant
E. OLIVEIRA, Undergraduate, FCT grant
F. RODRIGUES, Graduate, FCT grant
H. FONSECA, Graduate, FCT grant

Technical Personnel

M. M. SEQUEIRA
G. FERRADOR, (retired since August 2005)
J. M. OLIVEIRA
M. A. GAMEIRO, (retired since November 2005)
A. LIBÂNIO
M. A. TAVARES, (retired since February 2005)
M. A. PEREIRA

Collaborators

I. LOPES
M.M. MALTA

MinUrar- Uranium mines and their residues: health effects in the population

F.P. Carvalho, M.J. Madruga, M. Reis, J.G. Alves, J.M. Oliveira, I. Lopes, P. Duarte, O.M. Gil, M.L. Pedro, P.A. Cardoso, M. Malta, A. Libânio, L.M. Torres, L. Silva

Objectives

Portugal has a legacy of near sixty old uranium mining sites. Some of them, especially the site of Urgeiriça, were of a large scale mining and had facilities for uranium ore treatment. The residues contain elevated levels of radioactivity and, potentially, may expose the population to significant radiation doses with detrimental effects on health. This project was designed to investigate if a general population of Central Portugal, living within a short distance of abandoned uranium mines and its tailings show health effects associated with that exposure. The research encompassed measurement of radioactivity in environmental samples, including soil, water and agricultural products, radon in the atmosphere and environmental radiation doses, as well as a detailed clinical and genotoxic investigation in groups of human population living in counties (“freguesias”) with uranium tailings and in counties located far from the tailings. This project, also known by the acronym MinUrar, was funded by the Ministry of Health (500,000€), started in late 2002, and aims at assessing the radioactive contamination in the areas of uranium mining and milling, at assessing the exposure of population living in those areas to ionizing radiation and, ultimately, at assessing the effects on public health. It is a multi-disciplinary project with the participation of the National Institute of Health (INSA), the Geological Survey (former IGM, now INETI) and the Health Authority of the Centre of Portugal.

Results

Concentrations of radionuclides, such as uranium and thorium isotopes, ^{226}Ra , ^{210}Pb and ^{210}Po , were enhanced in mill tailings and in mine waters, as well as in surface waters near the facilities of uranium ore treatment. Concentrations of these radionuclides in contaminated soils may be up to 200 times higher than concentrations in agriculture soils of the region. With increasing distance to the tailings and mining waste heaps, the concentrations of radionuclides decrease rapidly to background values. The same trend is observed with environment radiation doses that may reach 20 $\mu\text{Sv/h}$ on U tailings and decrease to values near 0.2 $\mu\text{Sv/h}$ on agriculture fields. Therefore, radiation doses received by people living near the uranium mill tailings may be higher than the radiation dose from the natural background. Regarding toxic metals, despite the complexity of the element distribution patterns found, it was possible to recognize geochemical trends in the concentrations of a set of elements that is positively correlated with the vicinity of uranium mineralization and uranium mining works. In general, levels of radiation and toxic

metals were higher in the environment of counties with old mines and tailings than in most of the comparison counties. In the study on individuals, it was found that concentrations of Pb and Zn and also Cu in blood serum were higher in exposed population than in non-exposed population. Polonium (^{210}Po) in human hair was also higher in the population living near uranium mineralization and mining works.

The results show a slightly elevated exposure to ionising radiation and to heavy metals of population groups living near the uranium mines and mill tailings. The epidemiological study identified effects in public health in the same population groups when compared with reference groups of the population. The most plausible cause for the differences is the exposure to uranium mining residues.

The Scientific Report released in 2005 was awarded with a Distinction (“Menção Honrosa”) of the Public Health Prize Dr. Ricardo Jorge.



Published or in press work

1. F.P. Carvalho, J.M. Oliveira, M.J. Madruga, I. Lopes, A. Libânio, L. Machado. Contamination of Hydrographic Bassins Mining Areas of Portugal. In: *Uranium in the Environment, Mining Aspects and Consequences*, B.J. Merkel and A. Hasche-Berger Ed. Springer-Verlag Berlin Heidelberg (2005) 691-702.
2. J.M. Falcão, F.P. Carvalho, M. Leite, M. Alarcão, E. Cordeiro, J. Ribeiro *et al.* MinUrar- Minas de Urânio e seus Resíduos: Efeitos na Saúde da População. *Relatório Científico I*, July 2005, Publ. INSA, INETI, ITN pp. 147.

Environmental Radioactivity Survey Network ¹

M.J. Madruga, M.M. Sequeira, G. Ferrador, M.A. Gameiro, M. Reis, I. Lopes, M.A. Pereira, F.P. Carvalho, J.M. Oliveira, A. Libânio

The main goal of this national radiological survey consists on measuring artificial and natural radionuclides in environmental compartments (aquatic, terrestrial and atmospheric environments) considered as direct pathways of contamination to man. This programme has been planned in accordance with the European Network for Environmental Radioactivity, following the requirements of Artºs 35 and 36 of the EURATOM Treaty.

Around 400 samples have been collected accordingly to international sampling procedures and about 1000 analyses were performed for the determination of artificial and natural radionuclides, using gamma and alpha spectrometry, alpha/beta measurements and liquid scintillation technique. The determination of anionic and cationic concentrations in superficial waters, using the ionic chromatographic method has also been carried out. The results show that the Portuguese population was not exposed to radioactive contamination levels higher than the radioactive background. The estimated radiation dose to the Portuguese population due to inhalation and ingestion of the artificial and natural radionuclides measured in these samples has no significance from the point of view of radiological protection. The values obtained are much lower than those recommended to the radiological protection of the population (96/29 EURATOM Directive). Therefore, there is no need to adopt any recommendation for radiological protection. All the data were reported in Internal Reports, included into the database Easy Proteo 4.11 and sent to the EU Joint Research Centre, ISPRA, where later on were introduced into the European Database (REM).

¹ In coordination with DPRSN/Measurement Unit

Artificial Radioactivity in the Tagus Estuary ¹

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

The discharges of liquid waste containing artificial radionuclide into the sewage system of Lisbon have been detected and followed for years. Most of these radioactive discharges originate in the use of radioisotopes in hospitals. Other potential sources are nuclear powered ships, industrial facilities and research laboratories including the ITN. As a large fraction of the liquid waste from the city is discharged either treated or untreated into the estuary of the Tagus, the determination of concentrations has been made in sediment, water and fish samples collected monthly in various zones of the estuary between Sacavém and Algés. The most frequently detected radionuclides are ^{99m}Tc ($T_{1/2}$ = 6 h) and ¹³¹I ($T_{1/2}$ = 8 d). Both technetium and iodine are usually measured in environmental samples, including fish, especially in those collected near the discharge of main sewers, such as Alcântara and Terreiro do Paço, indicating that waste storage to allow for radioactive decay is insufficient or does not exist in some facilities. Nevertheless, radionuclide concentrations in water and fish are generally below 10Bq kg⁻¹ and, therefore, it is unlikely that they pose a significant radiological risk to the population.

¹ In coordination with DPRSN/Measurement Unit

SERVICES

1. Radioactivity in Drinking and Mineral Waters ¹

M.J. Madruga, G. Ferrador, M.M. Sequeira, E. Oliveira, A.R. Gomes, F. Rodrigues, J.M. Oliveira, I. Lopes

Following the Portuguese Law (Decree-Law nº243/2001) it is compulsory the evaluation of the radioactivity levels in drinking waters. For this purpose the DPRSN was requested by Water Suppliers to carry out the determinations of global alpha, global beta, Tritium, ²³⁸U, ²³⁴Th, ²²⁶Ra and ²¹⁰Po and the Total Indicative Dose parameter in drinking waters. The determination of radon in same water samples was also carried out. In order to obtain license to the commercialisation of mineral waters, an evaluation of its radioactive levels should be performed (Decree-Law nº84/90). The radiological study included analyses of ²³⁸U, ²³⁴Th, ²²⁶Ra, ²²²Rn, ²¹⁰Po and global beta. Several enterprises often request by this radiological study. During 2005, a total of about 1400 analyses were performed.

2. Radioactivity in Foodstuffs and other Samples ¹

M.J. Madruga, M. A. Gameiro, A.S. Lemos

By request of public and private enterprises, different kind of samples to be exported, mainly food samples and building materials were monitored. During this year 48 samples were analysed.

3. Indoor Radon

M.J. Reis, H. Fonseca

By request of public and private enterprises indoor radon measurements were performed in buildings. Since November 2003 a collaborative Protocol was established between DPRSN-ITN and DECO to answer the associate's indoor radon requests. A total of 160 measurements were performed during this year.

¹ In coordination with DPRSN/Measurement Unit

Radiological Protection and Radioactive Waste Management

Romão Trindade

The Radiological Protection and Radioactive Waste Management Group (PRGRR) pursued the development of the main activities already mentioned in the 2004 Annual Report

In general numbers, there was an increase in the requests panorama in all fields of assistance.

The licensing (entrance in national territory, possession, transport and transfer) of sealed sources for industrial, research, medical or other applications issued by PRGRR reached the number of 170 in the current year. The transport of radioactive materials is also another of the activities of this Group that is established in the Law.

Concerning the radioactive waste management activities in the National territory about 150 requests, for collection, segregation and treatment for interim storage were received at the Radioactive Waste Facility during 2005.

Ten incidents related to the detection of radioactive substances in scrap metal were reported by the industry and controlled by PRGRR

The verification of the radiological conditions of medical and industrial facilities (seven, in 2005) is undergoing strong modifications at different levels to better comply with the national legislation.

The PRGRR also developed intensive contacts with clients in all fields related to radiological protection and radioactive waste management, explaining what is required by Law, providing all the important paper work such as legislation, technical requirements, practical procedures and administrative steps as well as clarifying any doubts that might arise. This work is of paramount importance for the conclusion of the processes mainly in the case of radioactive wastes and sealed sources but also in all the other fields of intervention.

The activity of monitoring is another activity of the Group. The development of monitoring programmes for radioactive liquid discharges from hospitals in the public sewage of Lisbon Borough Council (CML) was continued in 2005 as well as the monitoring of the Campus radioactive liquid discharges.

Also in 2005 and in order to comply with both Articles 35° and 36° of the Euratom Treaty, PRGRR has installed the Campus gamma monitoring network (GAMMANET) to measure gamma radiation due to abnormal discharges in the environment.

A total of 296 gamma spectrometry analyses were carried out during 2005.

A new monitoring equipment has also been installed to more efficiently monitoring the radioactive liquid discharges of the Campus into the public sewer. To assist with both equipments, a grant was award by FCT to a graduate in Physics.

Continuing from the previous year, the PRGRR is participating in the co-coordination of a Degree thesis in Physics (University of Algarve) to study the application of Monte Carlo method to simulate and correlate different geometries and matrices for NaI detectors. This work has been accepted to be presented at the American Nuclear Society's 14th Biennial Topical Meeting of the Radiation Protection and Shielding Division.

The involvement of Group members in EU and IAEA projects, committees, working groups and task forces has increased in 2005 with the involvement in the Ad Hoc Working Party on Nuclear Safety (WPNS) EU.

In 2005, a PhD, in the field of radioactive waste management, was initiated with Faculdade de Ciências (FCUL) collaboration. Also this year, a member of the Group is starting a Master degree in Radiological Protection and Dosimetry (ITN/IST).

The Group has been involved in several training courses on Radiological Protection for industrial professionals.

Still concerning education and training, members of PRGRR have also been involved in a post-graduate course for Ordem dos Médicos in the field of radioactive wastes from medicine and in two Master Courses. One on Biomedical Inorganic Chemistry: Diagnostic and Therapeutical Applications (ITN/FCUL) and another on Radiological Protection and Dosimetry (ITN/IST).

Research Team

Researchers

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

Technical Personnel (Graduate)

L.M. PORTUGAL

Technicians

J. SEBASTIÃO
J. VENÂNCIO

Grants

P. DUARTE, ITN Grant (since Dec. 2004)
L. MADUREIRA, ITN Grant (since Nov. 2004 until Jul.2005)
L. BRÁS, ITN Grant (since Nov. 2002)

Characterization Of Suitable Areas For A Long-Term Radioactive Waste Repository Facility In Portugal

P. Duarte., I. Paiva, R. Trindade, A.Mateus¹

Introduction

Radioactive wastes in Portugal result mainly from the application of radioactive materials in medicine, research, industry, contaminated or irradiated scrap metal and from U-ores mining and milling activities. Sealed and unsealed sources (including liquid effluents and NORM) classified as radioactive wastes have been collected, segregated, conditioned and stored in the Radioactive Waste Interim Storage Facility (RWISF) since the sixties. The Department of Radiological Protection and Nuclear Safety (DPRSN) of the Nuclear and Technological Institute (ITN) is responsible for the RWISF management, located nearby Lisbon (Sacavém). Despite recent improvements performed at RWISF, the 300 m³ storage capacity will be soon used up if current average store-rate remains unaltered. Only in the last five years, about 700 requests to collect radioactive wastes were received at DPRSN and the number of conditioned sealed sources increased significantly for the same timeframe. Up to now, besides the 140 drums containing mostly ⁶⁰Co, ¹³⁷Cs, ¹²⁶Ra and ²⁴¹Am (incorporated in a cement matrix, Figure 1) that are stored at RWISF there are also 290 metallic drums containing compacted materials (such as gloves, papers, clothing and other contaminated items). Being aware of the tendency for radioactive waste production increase in Portugal and of the international rules and recommendations on disposal sites for this kind of wastes, it becomes clear that the Portuguese Radioactive Waste Interim Storage Facility must be updated. In this work, a Ph. D student is developing a study involving the DPRSN/ITN and Dpt.Geology/FCUL.

Objectives

The main objectives of this study are: to identify and select the most suitable area(s) to host near-surface repositories for low and intermediate radioactive wastes; to characterize the reference situation in geological and hydrogeological terms; to identify the radionuclide migration pathways in the selected areas and to apply and validate objective criteria to monitor the environmental impacts related to the disposal facility. Finally, it is expected this study to be part of the efforts to develop the future measures that will contribute for the practical resolution of the problems involving the radioactive waste management activities in Portugal.

Preliminary Findings

A first evaluation of suitable areas to host a new long-term radioactive waste storage facility was already been carried out using a Geographic Information System (GIS) base. Preference and exclusionary criteria were applied, keeping constant the map scale.

After processing exclusionary criteria (protected lands, aquifer systems and active faults), remaining areas (polygons) were scored by overlaying the preference criteria (population density, maximum seismic intensity, and annual average precipitation).

A composite score was determined for each polygon by summing the scores for all of the three preference criteria. Starting with an 80% cut-off of the maximum composite score, an area of 16049 km² was obtained (≈18% of the Portuguese mainland territory). In order to limit further more the calculated area, the results were re-analysed using a 90% cut-off, thus resulting a potential area of 8487 km² (≈ 10% of the Portuguese mainland territory). Work in progress will use this area as reference for site selection, crisscrossing appropriate criteria for scales ranging from 1:50000 to 1:25000.



Figure 1 – Examples of sealed sources conditioning within concrete drums to be disposed in a near surface repository.

¹. Dept. of Geology, FCUL.

A Contribution to the Analysis of the Activity Distribution of a Radioactive Source Trapped Inside a Cylindrical Volume, Using The Mcnpx Code

L Portugal., C. Oliveira, R. Trindade, I. Paiva

The increasing use of radioactive sources worldwide also increases the risk of an accident resulting from the loss of control of these sources. Orphan sources, activated materials or contaminated materials with natural or artificial radionuclides have been detected in scrap metal products destined to recycling. The consequences of the melting of a source during the process could result in economical, environmental and social impacts. From the point of view of the radioactive waste management, a scenario of 100 ton of contaminated steel in one piece is a major problem. So, it is of great importance to develop a methodology that would allow us to predict the activity distribution inside a volume of steel. It is our goal to distinguish different radius of spherical source geometries trapped inside the cylinder. For this we propose a methodology, using the Monte Carlo simulation and again the MCNPX Code, based on the ratio of the counts of two regions of the gamma spectrum. From a spectrum obtained with a sodium iodide detector, it is possible to calculate the ratio of the counts in the region of the characteristic photons of the source (for cobalt, between 1100 and 1400 keV) and the counts of a selected region in the lower energies. These calculated ratios allow us to determine a function $r = aR^2 + bR + c$, where R is the ratio between the counts of the two regions of the gamma spectrum and r is the radius of the source. To apply this methodology in a real scenario, it is necessary to acquire a spectrum of a cylinder containing the source. Based on the spectrum, the ratio between the counts of the two regions of the gamma spectrum is calculated. With the ratio and the function $r=f(R)$, previously determined, we are able to estimate the source radius.

Radioactive Liquid Discharges From Hospitals In Public Sewage Of Lisbon Borough Council (CML)

R.Trindade, L.Portugal, L.Brás, J.Venâncio, F.Gomes, P. Duarte, I.Paiva

A monitoring programme of radioactive liquid discharges from hospitals in the public sewage and Residual Water Treatment Plant (ETAR) of Lisbon was carried out in order to identify the radionuclides present and their activities. About 153 samples of liquid effluents were collected and analysed by quantitative and qualitative gamma spectrometry. This monitoring programme was requested by CML and this year also involved collection and analysis of samples from IPO's sewage. The monitoring programme was divided in two different programmes. In Programme I was involved the sequential collection of 4 discrete samples in 5 sampling points from nuclear medicine. In Programme II, 4 discrete samples were taken at the ETAR's of Lisbon. Sample were analysed by gamma spectrometry

Services

1. Radioactive waste management

Radioactive wastes from the national producers were collected, segregated, transported and conditioned in cement matrix or iron drums for interim storage at Radioactive Waste Facility. During 2005 about 150 requests for radioactive waste collection were received.

2. Radioactive liquid discharges from Nuclear and Technological Institute (ITN)

Samples of liquid effluents are analysed by gamma spectrometry. It was installed a submersible probe in Central Tanks, to carry out a radiological survey of radioactive liquid effluents from RPI, Chemistry Sector and Central Tanks before being discharged to the Residual Water Treatment Plant. The activities discharged are reported to the Radioactive Substances Committee of OSPAR Convention and art. 35° of Euratom Treaty.

3. Radioactive liquid discharges from Oncology Portuguese Institute (IPO), Coimbra

A radiological survey requested by IPO/Coimbra of radioactive liquid waste from the Retention Tanks before being discharged into the public sewage. Samples of liquid effluents were analysed by quantitative and qualitative gamma spectrometry.

4. Gamma network of Nuclear and Technological Institute (ITN)

In 2005 it was installed a gamma network, GAMMANET, to measure dose radiation in the environment in order to comply with art. 35° and 36° of Euratom Treaty.

5. Nuclear vessels radiological monitoring

An environmental radioactivity survey is carried out each time a nuclear vessel stayed at national harbours. The programme consisted on continuous monitoring of radioactive aerosols and airborne radioiodine, sampling of water, sediments and biological species for gamma spectrometry analysis. Sampling was done before, during and after the stay of the vessel. Results are reported to Ministry of Defence. In 2005, five nuclear vessels stayed at Portinho da Costa harbour, near Lisbon

6. Radioactivity in scrap metal

Radioactive material was detected and collected during a radiological survey, requested by the industry, of trucks containing scrap metal at a smelting factory. Ten cases of radioactive materials in scrap metal were detected this year.

7. Radiological safety verification at medical, industrial and research facilities

During 2005, the PRGRR carried out the verification of radiological safety conditions at seven public and private medical, industrial and research facilities.

8. Sealed sources licensing

According to Decree-Law n° 153/96 and Decree-Law n° 165/2002, requests of sealed sources were analysed and licences of entrance in the national territory (72), transfer (16), transport (18) and possession (62) were issued.

9. Radioactive cargo in transit

A radiological monitoring and the verification of international rules compliance were carried out when ships transporting radioactive cargo called Portuguese harbours.

Radiological Risk and Safety Assessment

A. D. Oliveira

In spite of the inclusion of the expression radiological risk in the name of this group, the activity was about safety assessment without truly enter in the field of radiation risk evaluation, mainly because the chronic problem of lack of human resources.

Biological effects of radiation is also part of this group whose activity is the application of techniques of chromosome painting with DNA fish probes and includes the cytogenetic analysis in blood samples of people exposed to radiation. This work is made only within the project MinUrar.

Further activities are cellular dosimetry, radiation physics and dosimetry and also radiation protection in interventional radiology. The work in Interventional radiology is a new project which is part of a "Coordination Action" sponsored by the EC within the 6th Framework Programme, WG 9 - Radiation

protection dosimetry of medical staff (CONRAD WP7).

Concerning the services requested by the General Directorate of Health of the Ministry of Health, that is to perform radiation safety reports, supporting its legal competence of licensing all the radiological installations of the country, we started to change our procedures, in agreement with the IAEA recommendations. We encouraged the owners of radiological installations, public or private, to accomplish its own radiation safety assessment previously the licensing process. With this purpose we developed new administrative and technical procedures, for example, a general radiation protection programs to help owners of facilities to implement their own.

Research Team

Researchers

A. D. OLIVEIRA, Aux , Group Leader
M. A. NEVES, Princ.
P. VAZ, Princ.
O. GIL, Aux.
M.L. PEDRO, Aux. (retired)

C.P. Santos, Graduate

Technical Personnel

M. A. COSTA, (transferred in May)
T. ANTUNES

Students

P. CARDOSO, Graduate, FCT grant
L.M.C. Marques, Graduate
A.C.A. Trillo, Graduate
C.A.A. Carrapico, Undergraduate

Collaborators

A.M. ROSA (retired)
D. ALVES

Radiological Safety Assessment

A.D. Oliveira, P. Vaz, M.A. Costa¹, T. Antunes²

Objectives and activity

As is mentioned in the introduction page, to respond to the requests of the General Directorate of Health of the Ministry of Health, as technical advisory, in its legal competence of licensing, is a very time consuming activity, not related with scientific research. In 2005 we make a total of 151 (0.6/dia) technical safety reports (Figure 1 and 2).

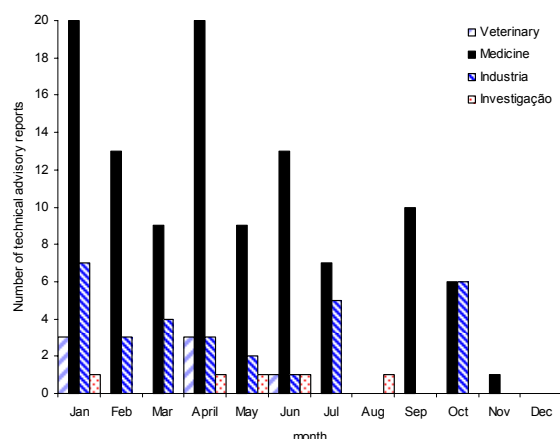


Figure 1 – Number of technical advisory reports by activity.

Actually, we function as regulatory authority, however without the legal competence, filling the gaps existing in the legislation. There are lacks in the legislation, regulations are nonexistent and the regulatory body don't work properly or simply just don't work. The inspections also don't work or they are not effective. The traditional way of doing authorizations in the country was to request to this small group the overwhelming work of the demonstration of safety of all the facilities and activities even when there are no regulations. This is completely against the IAEA Safety Standards.

The participation in the RASSC³ approached us close to the IAEA Safety Standards. In what concerns to the authorizations of radiological facilities and activities, the first income it was the recognition that Portugal is far from the right procedures in regulatory activities. To change this mentality is the big challenge we faced, finding more often than not difficulties at political level.

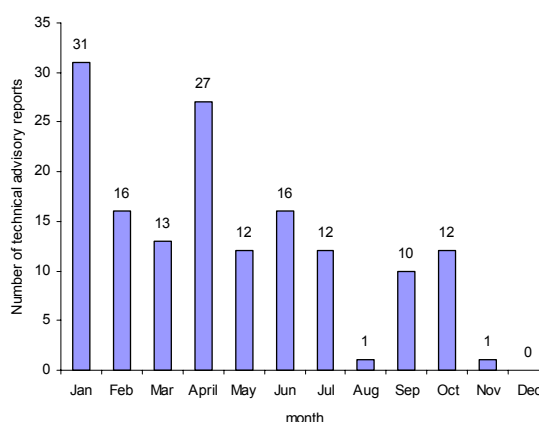


Figure 2 – Total number of technical advisory reports.

Mentioning, IAEA: “prior to granting of an authorization, the applicant shall be required to submit a detailed demonstration of safety”. After this the regulatory body shall review and assess the safety demonstration in accordance with clearly defined procedures. This is very clear but it is not what happens in Portugal. To contribute to the change of this situation we elaborated a typical radiation protection program with enough generality to be applied in most of the radiological practices and activities in accordance with the IAEA safety standards. Furthermore, we developed new forms and new procedures to respond to the requests of the General Directorate of Health. Surprisingly some facilities adapted themselves to this situation leading, for example, to research laboratories or industrial users with well defined radiation protection programs and radiation protection officer, that was a good result of our activity. At this point in time there is a general perception that the changes we started toward the IAEA recommendations are welcome.

See full list of internal reports, elsewhere in this reports.

Concerning the research activity, we started a project in interventional radiology in order to assess the dose of the workers.

¹ Transferred in May

² Since October

³ AD Oliveira is member of the RASSC (Radiation Safety Standards Committee) of the IAEA on behalf of Portugal.

Targeted radiotherapy and cellular dosimetry

M. Neves and A. D. Oliveira

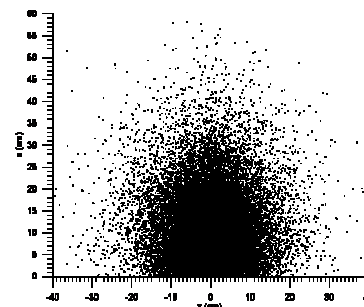
Targeted radionuclide therapy (with the exception of radioiodine treatment for thyroid disease) is a relatively new field. Internal dosimetry problems arise in two domains: radiation protection and accurate dose estimation, from macroscopic to cellular dimensions. An accurate calculation of the absorbed dose at the cellular level can lead to the optimization of the administered radioactivity and consequently the optimization of clinical response and minimization of radiation to healthy tissues. The choice of radionuclides with therapeutic interest, is based on the type and energy emission suitable for killing tumour cells when they grow as single and small, intermediate or large clusters. From the correlation between the EDC (equilibrium dose constant) and the average electron energies of reported therapeutic radionuclides we proposed new 20 ones suitable for single, intermediate and large clusters. A short analysis of their production was outlined.

The dosimetry at cellular level is based on both, analytical and Monte Carlo methods for particle transport calculations. We proceed with a compilation of available methods in cellular dosimetry to be applied to the new radionuclides.

Radiation physics, dosimetry and shielding

A.D. Oliveira, P Vaz

Radiation technology is widely applied in medicine, diagnostic and therapy, and one of the main aspects of this technology is radiation protection of professionals, members of the public and patients, which involves dose calculations. Computational simulation of the interaction of radiation with matter was one of the powerful methodologies in radiation technology used in studies of radiation physics and dosimetry, namely the description of the photon track evolution. Studies about deterministic and Monte Carlo methods in shielding design were carried out including both external and internal exposures of radiation. In shielding design our main goal is to stay up to date with existent methodologies.



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

P.A. Cardoso, M. Luísa Pedro, O. Monteiro Gil

We have proceeded with the work, started in partnership with INSA, into the evaluation of the biological effects of low-level ionizing radiation and genotoxic damage as a result of chronic exposure to ionizing radiation in populations living near old uranium mines and tailings. The project - «MinUrar» (“Minas de urânio e seus resíduos: efeitos na saúde da população”) aims at investigating the health effects in this populations due to exposure to radon and other radioactive elements. This project was funded by the Ministry of Health (Resolução da Assembleia da República nº 34/2001).

Until now we have already two groups completely studied, one from people living near the uranium mines (Canas de Senhorim) the other a control group in the centre-north region of the country, but not living near uranium mines. In this study, chromosomes 1, 2, 4 were analysed for chromosomal translocations, by the FISH technique (Fluorescent *In Situ* Hybridization).

For the first group (exposed group) we have studied 32 individuals, with a score of 67 683 metaphases, and for the non exposed group 33 individuals were studied with a total score of 69 199 metaphases. Between these two groups we didn't find any statistical difference in the number of aberrant cells. In parallel with these samples we performed an analysis of the same blood cells irradiated in vitro with 2 Gy gamma radiation for the challenge assay. This assay aims to determine the cell's competence for DNA damage repair. In the non exposed group a total of 23 874 metaphases were analysed and for the exposed group 23 642 were analysed.

At present we are evaluating the dose response curve ranged from 0-4 Gy, and for each point a total of 2000 metaphases will be studied. The study of a reference group (coming from the region of Alentejo) was also initiated, with the same objectives and criteria used in the two groups already studied.

Study of polymorphisms in a population of non familiar thyroid cancer patients

O.M. Gil, S.N. Silva¹, J. Gaspar¹, J. Rueff¹

The ERCC2 protein is an evolutionary conserved ATP-dependent helicase that is associated with a TFIIH transcription factor complex and plays an important role in nucleotide excision repair. Because polymorphisms have been associated with an increased risk for several types of cancers, we carried out an hospital based case-control study in a Caucasian Portuguese population to evaluate the potential role of these polymorphism on the individual susceptibility to thyroid cancer. The results obtained did not reveal a significant association between each individual polymorphism studied and an increased thyroid cancer risk, but individuals homozygous for non-wild-type variants are overrepresented in patients group.

Our results suggest that genetic polymorphism in this gene might be associated with individual susceptibility towards thyroid cancer, mainly papillary type tumours, but larger studies are needed to confirm these results.

¹ - Institute of Genetic, Department of Genetics, Faculty of Medical Sciences, New University of Lisbon, Portugal.

Synthesis, characterization and biodistribution of Sm-153 and Re-186 ligands in collaboration with national institutions (INETI and IBILI)

M. Neves, M. F. Teixeira¹, I. Antunes¹, F. Botelho², M. I. Prata², I Dormehl³, J. R. Zeevaart³, W. Lowe³.

Our contribution to the national and international projects (below referred), is the production of Sm-153 and Re-186, the optimization of reaction labelling with several ligands and their radiochemical characterization.

- *Novel indazolebisphosphonates for bone mineral metabolism: synthesis, molecular modelling and pharmacological activities.* 1-ITN-Instituto Tecnológico e Nuclear, Sacavém, Portugal, 2-INETI-Instituto Nacional de Engenharia e Tecnologia Industrial, Lisboa, Portugal,

- *Lanthanide(III) Complexes of Glycoconjugates for Lectin-Mediated Medical Imaging.* 1-ITN-Instituto Tecnológico e Nuclear, Sacavém, Portugal, 3-IBILI- Instituto Biomedico da Luz e Imagem, Coimbra, Portugal.

- *Assessment of ¹⁵³Gd(III)-EPTA-C16, a new self-assembling Gd(III)-chelate: biodistribution and gamma imaging of the ¹⁵³Sm(III)-labeled ligand.* 1-ITN-Instituto Tecnológico e Nuclear, Sacavém, Portugal, 3- IBILI- Instituto Biomedico da Luz e Imagem, Coimbra, Portugal.

- *Biodistribution and pharmacokinetics of variously molecular sized ¹⁸⁶Re-polyethyleneiminomethyl phosphonate complexes as potential selective therapeutic bone agents in the normal rats and in nude mice with xenotransplant of osteosarcoma model.* 1- IBILI-Instituto Biomedico da Luz e Imagem, Coimbra, Portugal, 2- University of Pretoria and 3- NECSA (Nuclear Energy Corporation of South Africa), Pretoria, South Africa.

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

P. Vaz (coordinator), I.F. Gonçalves, I. Paiva, R. Pires¹, R. Trindade

IP EUROTRANS is a European Union co-financed project (ref. FI6W-CT-2004-516520) in the 6th Framework Program EURATOM. It is devoted to the transmutation of high-level waste from nuclear power plants, which make up for about 35% of the European electricity production. The work is focused on transmutation in an Accelerator Driven System (ADS). Due to the fact that the strategy of partitioning and transmutation could reduce the radiotoxicity of high-level wastes dramatically and thus ease the discussion about the long-term safety assessment of a final repository, any step towards the technological realisation of transmutation in Europe will have a positive influence on the improvement of public acceptance of nuclear electricity production. An increasing acceptance of nuclear by society could lead to a nuclear revival in Europe, which in turn would reduce Europe's steadily increasing dependency on energy imports. The objective of IP EUROTRANS is the design and the feasibility assessment of an industrial ADS prototype dedicated to transmutation, together with the definition of a backup solution. IP EUROTRANS benefits from the scientific results and technological achievements of FP5 and is fully coherent with the ongoing FP6 IP EUROPART dealing with partitioning and the STREP RedImpact studying the impact of P&T on waste management. The necessary R&D results in the areas of fuel, technology and nuclear data will be made available, together with the experimental demonstration of the ADS component coupling. The outcome of this work will allow to provide a reasonably reliable assessment of feasibility and an estimate of cost for an ADS based transmutation, and to decide on the detailed design of an ADS and its further construction, if there is a more general decision to go ahead with ADS-based transmutation. IP EUROTRANS will strengthen and consolidate the competitiveness and international leadership of Europe in transmutation in comparison with other nations. The Portuguese team, led by ITN, participates in the following:

- DM1-DESIGN – “*Development of a detailed design of XT-ADS and a conceptual design of the European Facility for Industrial Transmutation EFIT with heavy liquid metal cooling*” – participating in:
 - WP 1.2 (“Development and Assessment of XT-ADS and EFIT Designs”)
 - WP 1.3 (“High Power Proton Accelerator (HPPA) Development”)
- DM2 – ECATS – “*Experiment on the Coupling of an Accelerator, a spallation Target and a Sub-critical blanket*”, participating in:
 - WP 2.2 (“Validation of the generic dynamic behaviour of an ADS in a wide range of sub-criticality levels and with consideration of thermal feedback effects”)

1 – Faculdade de Engenharia / Universidade Católica Portuguesa

Metrological Laboratory of Ionizing Radiation

João Cardoso

The Metrology Laboratory of Ionising Radiation (LMRI) develops work in the following activity areas:

- Research and training in metrology of ionising radiations.
- Maintenance of the ionising radiation national standards, under a protocol with the Portuguese Institute for Quality (IPQ).
- International cooperation with EUROMET, BIPM, IAEA, WHO and EA, in the field of interlaboratory comparison of standards and measurements.
- Collaboration and support of other research groups performing measurements or irradiations.
- Services of metrological control of measuring instruments, according to national regulation (Portaria 423/98).

The LMRI, since 2000, has implemented a Quality System (QS) according to the ISO 17025 standard. Again, this year, a great effort was made in order to ensure that the LMRI QS agrees with the requirements of the standard.

The LMRI participates in the Mutual Recognition Agreement (MRA), an international process leading to the mutual recognition of national measurements standards of calibration and measurement certificates issued by the national metrology laboratories and is being implemented among the Metre Convention Member States. From March 2005, the LMRI "Calibration and Measurements Capabilities" (CMC) are published in the BIPM database. These CMC's characterize the LMRI measurement capabilities describing the method of calibration, the uncertainty of the calibration, the traceability of the measurement standard and much more information. At the moment, the LMRI has 43 entries in his CMC file, corresponding to 43 different services provided in the laboratory. These CMC's are published in the site of BIPM and can be consulted in the following link; <http://kcdb.bipm.org/appendixC/search.asp?reset=1&met=RI>.

For the first time, the primary standard of air kerma for Co-60 radiation went to BIPM for an intercomparison with their primary standard. This was a very important intercomparison exercise because it gives recognition of equivalence to the primary standards of other countries. It was an objective that was being pursuit for several years and finally was done.

The LMRI also participate in an intercomparison, promoted by EUROMET, for the quantity personal dose equivalent, $H_p(10)$, for the X-ray radiation qualities N-30, N-60 and N-120, described in the standard ISO 4037-1. Intercomparisons of doses at radiotherapy level were performed in programmes run by IAEA/WHO.

Collaboration with other research groups, outside ITN, is maintained, and again this year the LMRI provided irradiation conditions and experimental facilities to several research groups outside ITN.

Calibration services were provided to the community mainly for industry, universities, hospitals, armed forces and departments of ITN.

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 423/98 from 21 of July. Metrological control includes calibration and type testing. During 2005 were calibrated 62 dosimeters and about 500 TLD dosimeters were irradiated. The following figures can quantify the work done in this particular area.

Instruments calibrated by type of use

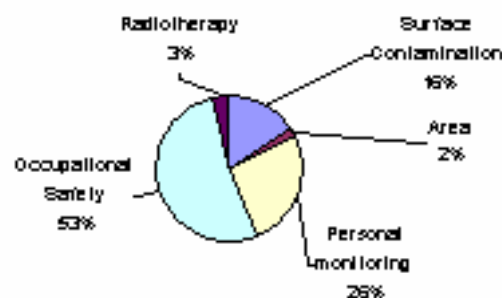


Figure 1. Distribution of calibrated instruments by type of use.

Instruments calibrated by users activity

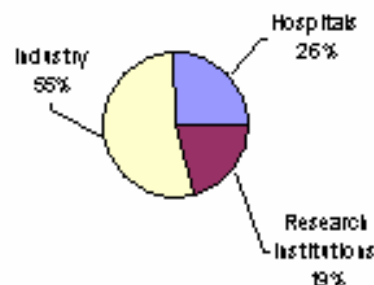


Figure 2. Distribution of calibrated instruments by area of activity.

Research Team

Technical Personnel

J. CARDOSO
L. SANTOS

Study of the Spatial Variation of the Air Kerma Backscatter Factor on the Standard ISO Phantom: Experimental and Simulation Evaluations

J. Cardoso, C. Oliveira, A. Ferro de Carvalho

The evaluation of effective dose received by exposed workers to ionizing radiation is done by personal dosimeters who perform measurements in the operational quantity, personal dose equivalent, $H_p(10)$, which estimates the effective dose. In agreement with the definition of $H_p(10)$, the calibration of instruments in this quantity is performed with a ISO water phantom. In the phantom front face can be positioned several dosimeters allowing a simultaneous irradiation, and to do this, is possible to define an area which boundary is the isodose contour of 95% of the dose in the centre of the front face. So, the diameter of this circular area, d_F , define the region where the radiation field is uniform and where must be positioned the dosimeters. The main goal of this work is the determination of d_F for 95% of the dose in the centre of the phantom front surface. For this purpose, the spatial distribution of the air kerma backscatter factor, B , in the phantom surface, was determined. The air kerma backscatter factor is defined as,

$$B = \frac{K_a(\text{phantom present})}{K_a(\text{free in air})}$$

In order to determine B , two complementary approaches are purposed: the experimental approach and the numerical simulation by Monte-Carlo method applying the MCNP code. The simulated and the experimental work have been performed for ^{60}Co and ^{137}Cs gamma sources and for the X-ray narrow spectrum ISO series for 30 kV, 40 kV, 60 kV, 80 kV, 100 kV and 120 kV.

Results

The dispersion of the photons in the phantom that increases the number of photons in the front surface of the phantom and also changes the photon spectra in that region as it can be seen in figure 1 for N-120 radiation quality. The values for the diameter of the circular area, d_F , that defines the region where the radiation field is uniform and where must be positioned the dosimeters, which corresponds to 98%

of the dose in the centre of the phantom front surface, obtained in his work and those from the ISO 4037 can be seen in figure 2.

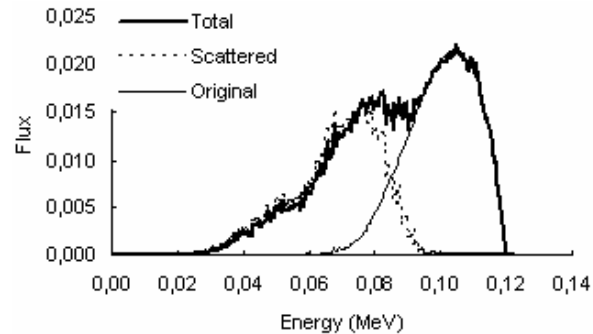


Figure 1: Photon spectra in the front surface of the ISO water phantom for N-120 radiation quality.

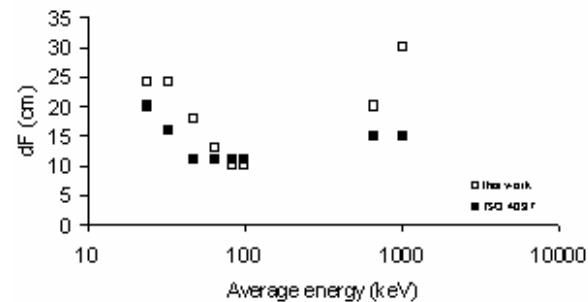


Figure 2: Values for d_F obtained for the radiation qualities presented in this work.

Conclusions

Some differences were found for the value of B calculated from the experimental method and by the simulation method. These differences reached the 7% value, with a tendency of higher B values for the simulation results. Comparing the results obtained in this work to those described in ISO 4037-3 it is clear that our results provide larger areas for positioning the personal dosimeters in the front surface of the ISO water phantom.

Measurement Unit

Nuno Rombert Pinhão

The Measurement Unit (MU) of DPRSN was created in January 2005 (following an expert visit to verify compliance with Artº 35 of the EURATOM treatise), with the aim of consolidating the radioactivity measurement laboratories under a single organizational unit. The MU, together with the laboratories of the Environment Radioactivity group (which is responsible for the chemical preparation of the samples), forms the infrastructure that carries out the fulfillment of Portugal's international obligations in the area of radioactive control of the environment.

The MU is composed of four laboratories:

- Gamma Spectrometry laboratory, equipped with six germanium detectors and one Si(Li) detector;
- Alpha Spectrometry laboratory, with a total of 41 surface barrier detectors;
- Total Alpha and Beta Countings laboratory, with two systems equipped with gas flow proportional counters, two liquid scintillation systems and two ZnS solid scintillators;
- Ion Chromatography laboratory, equipped with an ultra-pure water system and an ion exchange chromatograph.

The main task of the MU is to provide radioactivity measurement services:

- For the National Radiological Surveillance Program;
- to support economical activities, and
- together with the ion chromatography analysis, to support and collaborate on the research activities of other groups.

In the short term, the MU is also involved in the reorganization of the laboratories according to ISO 17025 standard. Preparations are under way for laboratory accreditation.

In parallel with these main task, the MU also conducts research and development on the analytical techniques used in this field. The Unit also promotes the profes-

sional qualification of the personal, and other related educational activities.

In 2005, the MU has undergone several transformation:

Infrastructure:

- Upgrade of the power support in the laboratories through the instalation of a power generator and the repair of a UPS unit to ensure unattended operation;
- repair, recover and upgrade of equipment;
- installation of a new laboratory facility for Ion Chromatography;
- installation of a network server and partial installation of a private network.

Measures to implement the ISO 17025 standard:

- Development of a customized data backup software application to allow the traceability of data;
- Implementation of uncertainty evaluation and expression of results according to ISO GUM and EA-4/16 recommendations;
- Aquisition of radioactive calibration sources;
- Participation in intercomparison exercises.

Training and education:

- Organization of courses on “*Measurement and Data Treatment*” and “*Detection and Measurement of Ionizing Radiations*”;
- two group members are involved in a Master degrees program;
- one FC/UL student is making the final year training in the MU;
- Participation in the activities of the Ciência Viva program through the activity “*Radioactivity measurement in environment samples by gama spectrometry*”

Research Team

Researchers

N.R. PINHÃO, Auxiliar

Analysis Contractor

L. SILVA, physicist

J. ABRANTES, physicist

L. MACHADO, chemical engineer

Technical Personnel

J. M. OLIVEIRA

G. SILVA

L. RAMOS

Students

G. CARVALHAL, MSc. Student, FCT grantee

R. MENDES, Undergraduate student, FC/UL

Analysis Services and Technical Assistance on Radioactivity Measurement and Ion Chromatography

J. Abrantes, G. Carvalhal, L. Machado, J. M. Oliveira, L. Silva and N. R. Pinhão

Objectives

The Measurement Unit provides analysis services on radioactivity measurement and ion chromatography for external entities and ITN groups. These services aim to support the following:

- the National Radiological Surveillance Program;
- economic agents that require radioactive analysis of food products or construction materials; and
- other groups' research activities.

Results

In 2005, effort was made to improve the accuracy of the results reported through the improvement of laboratory conditions, thorough statistical treatment of data, introduction of quality control practices on laboratory work, and revision of the analysis reports according to ISO recommendations.

In terms of the services offered, the range of ions measured by ion chromatography was extended to include NH_4^+ and F^- .

Analysis services

Almost 4300 analysis were conducted using the following techniques: alpha spectrometry (41,3%), total alpha or beta counting techniques (26,9%), gamma spectrometry (17,5%), liquid scintillation (9,5%), or ion chromatography (4,8%).

About 30,4% of these analyses were for the National Radiological Surveillance Program, 27,8% for external entities and 41,7% for research projects, either of DPRSN or other ITN sectors.

It is worth mentioning that 95% of the alpha spectrometry, 54% of the ion chromatography and 30% of the gamma spectrometry analysis were on samples for research projects of the DPRSN, Chemistry sector or Physics sector. This is the result of an effort to improve the laboratories' services, including to offer this type of analysis to groups outside the department and to involve the group staff on research projects.

Services for external entities, mostly companies in the private sector, represent 70% of the analysis based on total alpha or beta counting or liquid scintillation techniques, 6% of the gamma spectrometry analysis and 3% of the alpha spectrometry analysis.

In terms of value, and considering only the fraction of the price of the analysis attributed to services offered by the Unit, the external services represent an income of around 48 kEuros.

The analysis performed for the National Radiological Surveillance Program represent a total value of 148 kEuros.

Technical assistance

Technical assistance was provided for the configuration and calibration of alpha spectrometry equipment on EDM laboratories on Urgeiriça.

Considering the operational costs, we estimate that the results obtained in the Measurement Unit laboratories represent a net added value of over 70 kEuros.