

## Analysis of the Occupational Radiation Dose Data

M.B. Martins, J.G. Alves, A.R. Roda, J.N. Abrantes

### Objectives

The DPRSN of ITN is the main Institution in Portugal dedicated to the individual monitoring of external radiation. Individual monitoring of external radiation is performed at DPRSN using two on-going control methodologies, one based on film dosimetry (since 1957) and the other one based on thermoluminescent detectors (since 1996). The workers are monitored on a monthly or quarterly basis. All the workers monitored by DPRSN are controlled with respect to X and gamma radiation using whole body dosimeters worn on the trunk, in the position of likely maximum exposure.

The monitored workers belong to four different fields of activity, namely health or medicine, conventional industry, research and mining distributed from several facilities. People working at the research reactor of ITN have been included in the research group.

This work has three main aims: 1) Creation of a database with the occupational radiation doses for external radiation received by the workers monitored; 2) Analysis of the number of monitored workers grouped by fields of activity and by facilities; 3) Distribution of effective dose per dose interval and professional categories in blocks of five year periods according the European Union Directive 96/29 EURATOM and the European Study of Occupational Radiation Exposure (ESOREX).

### Results

Annual effective doses measured with film were introduced in database format as previously reported data were registered on paper. The database was developed using MS-Access software and it contains all the collected information concerning the facilities, practices and the assessed doses of all monitored workers.

This database allows a fast print out of the individual annual doses and the respective lifetime dose for each controlled worker.

At present, the assessed doses are kept in independent databases, one for each method of control.

Since 1957 until 2001, a total of 217,714 records were produced at DPRSN, 167,390 relative to workers controlled by film and 50,324 relative to workers monitored with TLDs (Fig. 1).

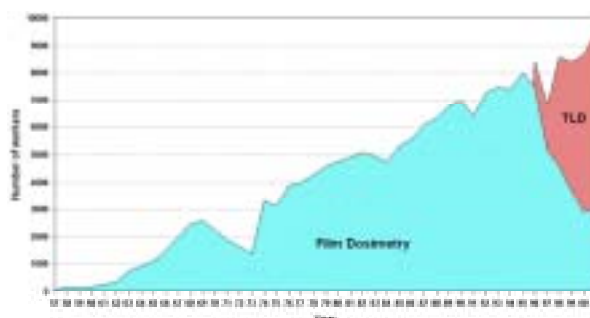


Fig. 1- Number of workers controlled by film and by TLD.

The number of monitored workers distributed by the fields of activity already mentioned using both methodologies are presented in Figure 2. According to the data, the medical applications are the field of work that involves the largest number of controlled workers.

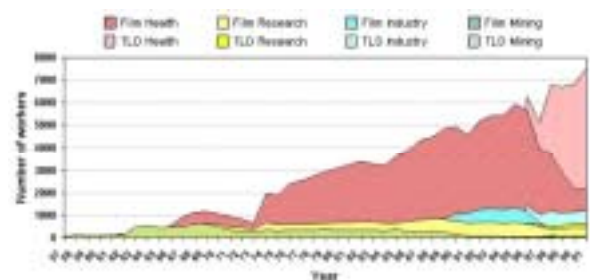


Fig. 2 - Number of monitored workers grouped by field activity for Film and TLD.

All this laborious work began during the last months of 2001. At present only the first goal and a part of the second one have been reached.

### Published, accepted or in press work

1. J.G. Alves, M.B. Martins, J. Abrantes. Databases in use at the Individual Monitoring Service of ITN-DPRSN. *1<sup>st</sup> International Meeting on Applied Physics (APHYS-2003), 13-18 October Badajoz, Spain, 2003.*
2. J.G. Alves, M.B. Martins, A.R. Roda, J. Abrantes. Occupational Exposure in Portugal in 1996-2002 in 5 year periods. Accepted for presentation at the *11<sup>th</sup> Int. Congress of the International Radiation Protection Association, May 23-28, Madrid, Spain, 2004.*

## The National Registry of Individual Doses

M.B. Martins, J.G. Alves, A.R. Roda, J.N. Abrantes

### Objectives

The recently published Decree-Law 165/2002 of 17 July commits to the DPRSN the task of keeping a record of the radiation doses received by workers during their life time. The legislation also requires that the dose records will be kept for 30 years.

Individual dosimetry started at DPRSN (then Serviço de Protecção Contra Radiações of J.E.N.) to ensure the dosimetry of the nuclear reactor staff, in 1957 using film badges. With time, the dosimetry service was expanded and provided to workers across the country. Technological developments allowed for the introduction of thermoluminescent dosimetry in 1996, and today most of workers are monitored by TLD.

The DPRSN prepared itself for this responsibility of becoming the National Registry of Doses, and gradually all the historic records from JEN, on paper

support, were introduced in the data base. This effort has been completed during 2003.

Today, the Dosimetry Service of DPRSN is able to provide individual life-time integrated doses in a few minutes for all the workers recorded in the data base.

### Published, accepted or in press work

1. M.B. Martins, J.G. Alves, A.R. Roda, J. Abrantes. Towards a National Dose Registry in Portugal. Accepted for presentation at the *11<sup>th</sup> Int. Congress of the International Radiation Protection Association, May 23-28, Madrid, Spain, 2004.*



## Support to the Implementation of a Radiation Protection System in Portugal

F.P. Carvalho, J.G. Alves, M.B. Martins, A.F. Carvalho

### Objectives

Portugal stays far behind the adoption of the International Basic Safety Standards in Radiation Protection of workers and the public. There are European Directives to be transposed to the National Law and recommendations from international organizations to build up a radiation protection system with an independent authority.

The DPRSN participates in an European regional project set up by the AIEA (RER/9/062) to improve the current situation and to enhance awareness of radiation protection and safety recommendations.

### Results

In the framework of this project we took part in IAEA regional meetings to discuss the radiological protection infrastructures existing in Member States, as well as to identify the gaps and needs for IAEA assistance. Part of this effort is also directed to enhance the safety and security of radiation sources worldwide.

Portugal is one of the few countries in western Europe that lacks suitable radiation protection infrastructures in place. Upcoming new members of the European Union, from East Europe, have wisely used the IAEA support to organize radiation protection and are now better prepared than Portugal to comply with safety rules and EU Directives.

During 2002, an IAEA Peer Review mission of experts, aimed at assessing the existing national legal and technical infrastructures for radiation protection and nuclear safety in order to provide advice to the country, had been planned. This mission was postponed several times at the request of ITN and did not take place.

In the framework of this IAEA supported activities, several ITN fellows and staff from radiological services of Hospitals were awarded with fellowships and could attend specialized training courses abroad. Three National training courses on radiation protection were organized by DPRSN and provided to industry workers.

Following requests from the Ministry, intensive collaboration in technical issues was also provided by DPRSN, in the transposition of EU Directives into the national legislation.

### Published, accepted or in press work

1. F.P. Carvalho, J.G. Alves, M.B. Martins, A.F. Carvalho. Infrastructures for Radiation Safety in Portugal. *International Conference on National Infrastructures for Radiation Safety: Towards Effective and Sustainable Systems, Rabat, Morocco, 1-5 September 2003.*

## Optimization of the DPRSN TLD-Individual Monitoring System

J.G. Alves, V.I. Batel<sup>1</sup>, O. Margo and R. Montezuma

### Objectives

The main objective is to improve the routine work of the Individual Monitoring Service based on thermoluminescence dosimetry (TLD).

### Results

To achieve this goal two main aims have been established: 1. Implementation of methods for the continuous evaluation and analysis of quality control (QC) parameters; 2. Accreditation of the service by IPQ-Instituto Português da Qualidade.

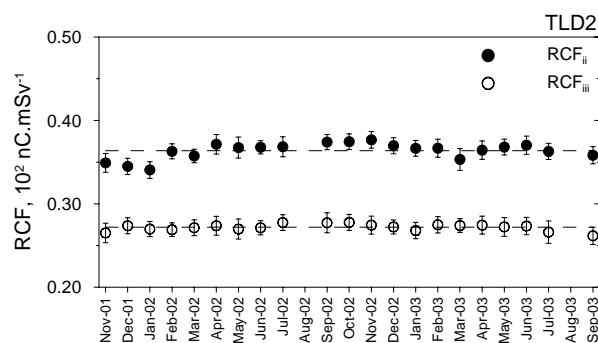
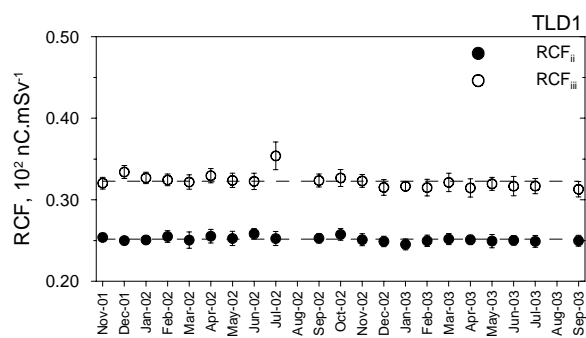
Simple routine tests were implemented to evaluate the system's performance and for the simultaneous determination of important QA/QC parameters. Sensitivity changes influencing the response of the TLD system and the dose evaluation method are being evaluated. Type testing using radiation qualities and phantoms described in the ISO 4037 are being performed along with an evaluation of the overall uncertainty. QC charts with defined acceptance, action and rejection levels are being prepared.

All the important procedures followed in routine work are being written down in order to prepare the

necessary items for the accreditation of the service by IPQ-Instituto Português de Qualidade.

### Published, accepted or in press work

1. J.G. Alves, R. Montezuma, O. Margo and L. Santos. Study on Quality Control Parameters of a TLD System for Individual Monitoring. *1<sup>st</sup> International Meeting on Applied Physics (APHYS-2003), 13-18 October Badajoz, Spain, 2003.*
2. J.G. Alves, O. Margo and L. Santos. Quality Control in Individual Monitoring: Evolution of QC Parameters. Accepted for presentation at the *ICRS-10 – RPS 2004 Conference, 9-14 May Madeira, Portugal, 2004.*
3. J.G. Alves, V.I. Batel, J. Cardoso and L. Santos. Studies on the response of the personal dosimeter in use at ITN-DPRSN. Accepted for presentation at the *11<sup>th</sup> Int. Congress of the International Radiation Protection Association, May 23-28, Madrid, Spain, 2004.*



<sup>1</sup>MSc student, at Hospital de Santa Maria, Serviço de Radioterapia, Av. Prof Egas Moniz, 1649-035 Lisboa

## Harmonisation of Individual Monitoring in Europe

J.W. van Dijk<sup>1</sup>, P. Ambrosi<sup>2</sup>, T. Bolognese-Milsztajn<sup>3</sup>, L. Currivan<sup>4</sup>, R. Falk<sup>5</sup>, E. Fantuzzi<sup>6</sup>, M. Figel<sup>7</sup>, J.G. Alves<sup>8</sup>, M. Ginjaume<sup>9</sup>, H. Janzekovic<sup>10</sup>, V. Kamenopoulou<sup>11</sup>, M.A. Lopez<sup>12</sup>, M. Luszik-Bhadra<sup>13</sup>, P. Olko<sup>14</sup>, H. Stadtman<sup>15</sup>, C.M. Castellani<sup>16</sup>, F. Vanhavere<sup>17</sup>, E. Vartiainen<sup>18</sup>, W. Wahl<sup>19</sup>, A. Weeks<sup>20</sup> and C. Wernli<sup>21</sup>

### Objectives

This is a working group of EURADOS the European Radiation Dosimetry organisation.

The main objective of the work carried out is to achieve harmonisation of individual monitoring (IM) in Europe.

General objectives are: to look at the continuing efforts of quality assurance programmes of the various dosimetry services, to discuss and initiate measures to improve the situation in the field of IM, and to look at the new developments in instrumentation and testing.

### Results

Four subgroups are currently working under this EURADOS project. Each is dedicated to the following subjects: SG1 – Implementation of standards, SG2 – Harmonization policies for the integration of results from internal and external occupational exposure, SG3 – Electronic dosimeters for individual monitoring and other new developments, and SG4 – Quality assurance, quality control and reliability of dosimetric systems.

The main goal of SG1 is to go into more detail on standards and recommendations that directly deal with the dosimetric quality assurance of an IM service. A first draft (E. Fantuzzi, P. Ambrosi, E. Vartiainen, J.G. Alves, H. Janzekovic. Implementation of Standards.

Draft open for discussion), was prepared with the contributions of the members of the subgroup and was made available to all the members of the working group for discussion. Following the meetings in Braunschweig and later on in Bologna new directions were defined aiming at a more practical work directly dealing with the accreditation of an IM Service. The work evolved to the various steps worth mentioning and the necessary written down procedures to achieve accreditation.

The activities of the other SGs involved the preparation of surveys according to their respective subjects. The surveys were distributed amongst the members of the working group for completion or further distribution to the particular Institution or Service in each country.

### Published, accepted or in press work

1. E. Fantuzzi, P. Ambrosi, J.G. Alves, H. Janzekovic E. Vartiainen. Implementation of Standards in Individual Monitoring for External Radiation within the EU Member States, New Member States and Switzerland. *(Draft) Reports by the EURADOS working group "Harmonization in Individual Monitoring". To be published in Radiat. Prot. Dosim.*

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<sup>1</sup>NRG-RE, Utrechtseweg 310, PO Box 9034, 6800 ES Arnhem, The Netherlands.

<sup>2</sup>PTB, Bundesallee 100, D-38116 Braunschweig, Germany.

<sup>3</sup>IPSN, Rue Auguste Lemaire BP 6, F-92265 Fontenay-aux-Roses, France.

<sup>4</sup>RPII, 3 Clonskeagh Square, Dublin 14, Ireland.

<sup>5</sup>SSI, S-17116 Stockholm, Sweden.

<sup>6</sup>ENEA-IRP, Via dei Colli 16, 40136 Bologna, Italy.

<sup>7</sup>GSF, Ingolstadter Landstrasse 1, 85764 Neuherberg, Germany.

<sup>8</sup>ITN-DPRSN, Estrada Nacional 10, 2686-953 Sacavém, Portugal.

<sup>9</sup>INTE-UPC, Diagonal 647, Barcelona, Spain.

<sup>10</sup>HIRS, Parmova 33, 1000 Ljubljana, Slovenia.

<sup>11</sup>GAEC, 153 10 Ag. Paraskevi-Attiki, PO Box 60092, Athens, Greece.

<sup>12</sup>CIEMAT, Avda Complutense 22, 28040 Madrid, Spain.

<sup>13</sup>PTB, Bundesallee 100, D-38116 Braunschweig, Germany.

<sup>14</sup>INP, Radzikowskiego 152, PL 31442 Krakow, Poland.

<sup>15</sup>ARCS, A-2444 Seibersdorf, Austria.

<sup>16</sup>ENEA-IRP, Via dei Colli 16, 40136 Bologna, Italy

<sup>17</sup>SCK-CEN, Boeretang 200, 2400 Mol, Belgium.

<sup>18</sup>STUK-Personal Dosimetry, PL 4, FIN 00881 Helsinki, Finland.

<sup>19</sup>GSF, Ingolstadter Landstrasse 1, 85764 Neuherberg, Germany.

<sup>20</sup>BNFL RVT, Berkley Centre, 4L13 4PB Berkley Gloucestershire, United Kingdom

<sup>21</sup>PSI, CH-5232 Villigen PSI, Switzerland.

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

O. Monteiro Gil, P.A.M. Cardoso, M. Luisa Pedro, R.G. Vieira, J.H. Pereira Luis

### Objectives

The DPRSN team on cytogenetics initiated a research project that aims to study the biological effects of low-level ionizing radiation and evaluation of the genotoxic damage as a result of chronic exposure to ionizing radiation in populations living near the old uranium mines and tailings.

This research is carried out in partnership with a similar cytogenetics research group of the Instituto Nacional de Saúde Dr. Ricardo Jorge (INSA). This is part of a wider research project, designated by «MinUrar» (“Minas de urânio e seus resíduos: efeitos na saúde da população”) led by INSA. Participating institutes are, ITN/DPRSN, IGM, Centro Regional de Saúde Pública do Centro, Ministério da Saúde – Administração Regional de Saúde da Zona Centro, Hospital de S. Teotónio, SA-Viseu. This project is funded by the Ministry of Health. The project encompasses investigation in environmental contamination caused by uranium mining activities and effects on public health.

### Methods

The DPRSN team initiated the research project ‘MinUrar’ by testing and tuning up in conjunction with INSA, suitable techniques to investigate the health effects in the populations living near uranium mines due to exposure to radon and other radioactive elements. Upgrade of the laboratory and purchase of adequate equipment was also an initial step. The possible incidence of diseases or other health problems resulting from exposure to genotoxic contaminants, is determined through the search of chromosomal translocations in lymphocytes from peripheral blood cells. This is done with the FISH technique (Fluorescent *In Situ* Hybridization) and image analysis.

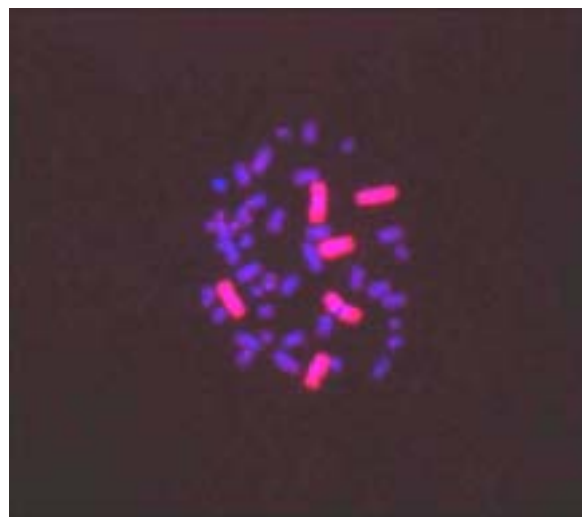
### Results

After selection and interviews with people living in the study areas, blood samples were collected in the villages by haematologist technicians from the Hospital S. Teotónio. Blood samples were transported to INSA, properly handled and stored. Cell cultures of blood samples from the target population were prepared in the laboratory. This includes samples from a group of people living near the uranium mines (Canas de Senhorim) and a control group in the centre-north region of the country, but not living near the uranium mines.

The cytogenetic research plan foresees analysis of blood cells irradiated with 2 Gy gamma radiation for the challenge assay and analysis of non-irradiated blood samples. The challenge assay aims to determine the competence of DNA repair. Chromosomes 1, 2 and 4 are analysed for chromosomal translocations.

In this investigation 2000 metaphases will be studied in the non-irradiated samples and 700 metaphases will be screened in the irradiated samples.

This epidemiological study is expected to attain final results by 2005.



Normal metaphase obtained by whole chromosome painting for chromosomes 1, 2 and 4.

### Published, accepted or in press papers

1.J. H. PEREIRA LUÍS, Low-dose Ionizing Radiation Effects and Hormesis, *Proceedings do Congresso da Sociedade Portuguesa de Pediatria, A Criança e as Radiações que Riscos?* pp.50, Fevereiro 2003.

2. J. H. PEREIRA LUÍS, Efeitos Biológicos e Riscos de Exposição às Radiações, *Congresso da Sociedade Portuguesa de Pediatria, A Criança e as Radiações que Riscos?* Lisboa 25 de Fevereiro 2003, communication.

3.J. H. PEREIRA LUÍS, Riscos de Exposição às Radiações Ionizantes, *Proceedings 7º Forum Nacional de Medicina do Trabalho*, pp 34, Lisboa, Outubro 2003

## Cytogenetic alterations induced by $^{131}\text{I}$ in peripheral blood lymphocytes from thyroid cancer patients

Octávia Monteiro Gil (\*)

### Objectives

This work aims at investigating chromosomal instability in peripheral blood lymphocytes of patients suffering of non familial thyroid cancer. Different polymorphic genes in this population of patients are also investigated for the susceptibility to this type of cancer.

After treatment with  $^{131}\text{I}$  we investigate the possible cytogenetic alterations and adaptive response induced by  $^{131}\text{I}$  in peripheral blood lymphocytes of patients.

### Results

During the reporting period I have completed the curricular subjects requested in the Doctoral Plan of the Faculty of Sciences of the University of Lisbon. This, together with the previous years and on-going experimental research is part of a PhD thesis untitled “Carcinoma da tiróide: caracterização genética e citogenética de uma população de doentes antes e após terapêutica com iodo-131”.

Experimental results obtained in previous years, through examination of blood samples donated by thyroid cancer patients undergoing  $^{131}\text{I}$  treatment in Department Nuclear Medicine, IPO, Lisbon, were completed.

The results were analysed and statistically treated, leading to the preparation of manuscripts submitted for publication in international journals.

### Future work

The experimental work will be resumed in the near future. For this purpose, a new set of patients will be selected in the hospital and blood samples will be taken.

This work is planned to be finished in 12 months, and it has been possible through kind permission of ITN-DPRSN to facilitate my partial displacement and collaborative work at the hospital and at the New University of Lisbon.

### Published, accepted or in press papers

1. N. G. Oliveira, M. Castro, A. S. Rodrigues, I. C. Gonçalves, O. Monteiro Gil, A. P. Fernandes, J. M. Toscano-Rico and J. Rueff (2003) Wortmannin enhances the induction of micronuclei by low and high LET radiation. *Mutagenesis*, **18**: 37-44.
2. J. Gaspar, S. Rodrigues, O. Monteiro Gil, I. Manita, T. C. Ferreira, E. Limbert, L. Gonçalves, J. Esperança Pina and J. Rueff (2003) Combined effects of glutathione S-transferase *GSTM1*, *GSTT1* and *GSTP1* polymorphisms and thyroid cancer risk. *Cancer Genetics and Cytogenetics* (accepted for publication).

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\* Work performed in the Department of Genetics of New University of Lisbon, under the supervision of Prof. J. Rueff.

## Computational dosimetry

A.D. Oliveira

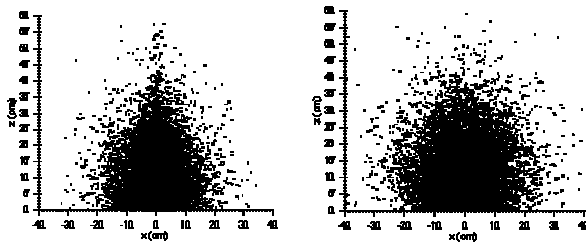
### Objectives

Studies in photon track structure and application of entropy to radiation physics.

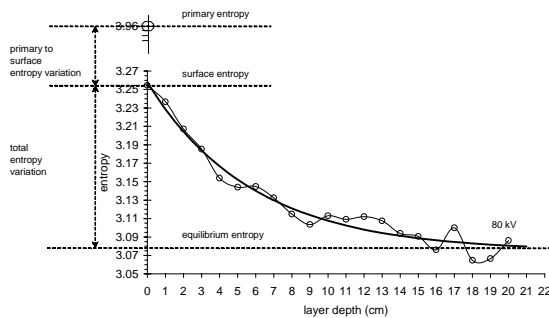
### Results

We participated in the Inter-comparison on the usage of computational codes in radiation dosimetry organized by "QUADOS" a concerted action of the European Commission.

The photon track study was developed introducing several probability distribution related with the step  $j$  of the probability  $P(E,j)$  that is the probability that  $j$  secondary interactions will occur during the degradation of a photon energy  $E$ . Examples of step 1 and 5 are shown in next figure



Studies in entropy of the energy deposited were also continued from previous years towards new perspectives in radiation physics and biophysics as illustrated in the next figure.



### Published, accepted or in press work

- A.D. Oliveira. Air kerma backscatter factor determined by Monte Carlo using extrapolation procedures from energy deposited data, *Workshop on Intercomparison on the usage of computational codes in radiation dosimetry*, Bologna, Italy, July 2003, oral.
- A.D. Oliveira. Esboço de um programa de protecção radiológica: do trabalhador à autoridade reguladora, *X Jornadas Portuguesas de Protecção Contra Radiações*, Lisboa, 2003, oral.
- A.D. Oliveira. Entropy of backscattering and energy deposited in water by low energy photons, *1<sup>st</sup> International meeting on applied physicsw, APHYS-2003*, Badajoz, 2003, poster.
- A.D. Oliveira, Analysis of the photon track structure for low energy photons, *11<sup>o</sup> International Congress of the International Radiation Protection Association, Madrid, Spain, 2004*.
- A.D. Oliveira, Entropy and photon track structure, *11<sup>o</sup> International Congress of the International Radiation Protection Association, Madrid, Spain, 2004*.
- A.D. Oliveira, Photon track evolution, *ICRS-10, RPS 2004, Madeira, Portugal*,



## Cellular dosimetry studies in targeted radiotherapy

A. D. Oliveira, L. Silva, M. A. Neves

### Objectives

Application of analytical methods in cellular dosimetry assuming non-homogeneous deposition of radionuclides in tissues to study the energy dependence of absorbed dose in cell cluster models.

### Results

We fixed a spherical cellular model with a spherical nucleus with radii  $R_c$  and  $R_N$ , respectively, and studied the effect of different values of  $R_c$  and  $R_N$  in the calculation of the dose in the cell nucleus. One of the important aspects in this analytical calculation is the determination of the geometry factor. We developed a Monte Carlo code for the computational determination of the geometry factor that can be applied in more complex geometries.

As a test to this Monte Carlo approach we compared the point-pair distance distribution which is related with the geometry factor for a sphere as both source and target obtaining the result shown in Figure 1.

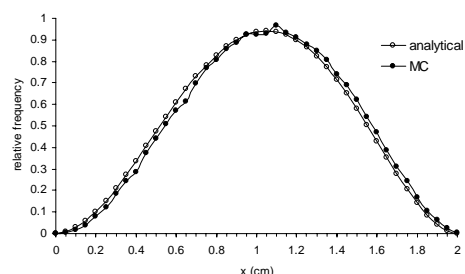


Figure 1 – Point-pair distance distribution which is related with the geometry factor.

This work is still in progress aiming to reach a complete procedure to dose determination at the cellular level including non-homogeneity in the deposition of radionuclides.

### Published, accepted or in press work

- M. NEVES A. KLING and A. OLIVEIRA. Targeted Radiotherapy: Radiobiological Selection of Nuclides. *Physics in Medicine and Biology* (submitted).
- L. SILVA, A.D. OLIVEIRA and M. NEVES, Cellular dosimetry studies in targeted radiotherapy, *ICRS – 10, RPS-2004, Madeira, Portugal (2004)*.
- M. NEVES and A. KLING. Potential Radionuclides for Targeted Radiotherapy. *ICRS-10 and RPS-2004, Madeira, Portugal (2004)*.

## Synthesis, characterization and *in vitro* and *in vivo* studies of $^{153}\text{Sm}$ -phosphonates

M. A. Neves, C. Geraldes<sup>1</sup>, M. I. Prata<sup>1</sup>, A. C. Santos<sup>2</sup>, M. C. Costa<sup>3</sup>, C. Rodrigues<sup>3</sup>, F. Teixeira<sup>3</sup>, H. Raminhos<sup>3</sup>, I. Pereira<sup>3</sup>

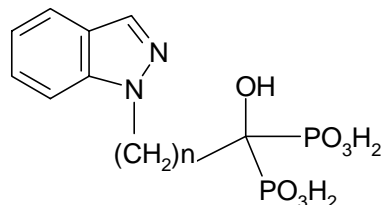
### Objectives

The aim of this work is the production of radiolanthanides as  $^{153}\text{Sm}$ , at the Portuguese Nuclear Reactor, and to participate in the synthesis, characterization and *in vitro* and *in vivo* studies of  $^{153}\text{Sm}$  phosphonates in projects proposed by others national institutions.

### Results

- Collaboration with the Biochemistry Department and IBILI of the University of Coimbra in hydroxyapatite (HA) binding, scintigraphic and biodistribution studies of  $^{153}\text{Sm}$ -DOTP<sup>5</sup> and  $^{111}\text{In}$ -DOTP<sup>5</sup>. The results were compared with MRI Ga-DOTP<sup>5</sup> studies. HA binding revealed that Gd-DOTP<sup>5</sup> is MR silent when bound to bone, likely because of the exclusion of all outer sphere water molecules from the surface of the complex, indicating a novel strategy for creating sensitive switchable MRI contrast agents.
- Collaboration with INETI/Lisbon in the synthesis and characterization of  $^{153}\text{Sm}$ -aminobisphosphonates and  $^{153}\text{Sm}$ -indazolbisphosphonates.

- 1- Biochemistry Department/Univ.Coimbra  
 2- IBILI/Univ. Coimbra  
 3- INETI/Lisbon



(n= 1, 2, 3, 4)

### Published, accepted or in press work

1. Alves FC, Donato P, Sherry AD, Zaheer A, Zhang S, Lubag AJM, Merritt ME, Lenkinski RE, Frangioni JV, Neves M, Prata MIM, Santos AC, de Lima JJP, Geraldes CFGC. Silencing of gadolinium(III)-phosphonate magnetic resonance contrast by hydroxyapatite binding. *Investigate Radiology*, Vol. 38 (12):750-760 (2003).
2. Geraldes CFGC, Prata MIM, Santos AC, de Lima JJP, Alves FC, Neves M, Sherry AD, Lenkinski RE. Silencing of gadolinium(III)-phosphonate MRI contrast by hydroxyapatite binding. *11<sup>th</sup> International Conference on Biological Inorganic Chemistry*, Cairns, Australia, 19-23 July 2003. Proceedings publicados no *Journal of Inorganic Biochemistry*. Vol. 96 (1): 137 (2003).
3. H. Raminhos, M. C. Costa, M. Neves, C. Rodrigues, M. J. Marcelo Curto. New Approach in the Synthesis of Third Generation Bisphosphonates. *5<sup>o</sup> Encontro Nacional de Química Orgânica & 1<sup>o</sup> Simpósio Luso-Japonês*, Universidade de Aveiro, Portugal, 1-4 de Julho de 2003

## Services

### Individual Monitoring of External Radiation

At DPRSN there are two dosimetric systems running simultaneously, one based on film and the other one on thermoluminescence dosimetry (TLD).

In 2003, approximately 9,860 professionally exposed workers from 1,056 facilities from all around the country were monitored corresponding to approximately 59,880 assessed doses.

Considering the monitored population in Portugal, four fields of work are available, namely, health or medicine, industry, research laboratories and mining, which are respectively identified by the acronyms MED, IND, INV and MIN.

Each service developed its own database to gather the information relative to the facilities that request individual monitoring, to the workers that are monitored and for the storage of the evaluated dose data. The databases were home developed using MS-Access® and are currently in use. They were originally developed in order to meet the needs of each monitoring method either based on film or on TLD, and in this way, were created independently one from the other.

The main aim of either database is to enable the user full access to the data related to the facilities, monitored workers and measured doses and at the same time to give an answer to all the administrative features necessary to keep the service running.

#### Film dosimetry

M.B. Martins, G. Rangel, M.A. Gameiro, J.M. Paiva, A.R. Roda, J.N. Abrantes.

Film monitoring is based on the Kodak type II film inserted in a homemade holder for the evaluation of  $H_p(10)$ .

In 2003 about 3,060 workers (aprox.) from 312 facilities professionally exposed to ionizing radiations were controlled. The numbers of monitored workers distributed by fields of activity are presented in Figures 1 and 2.

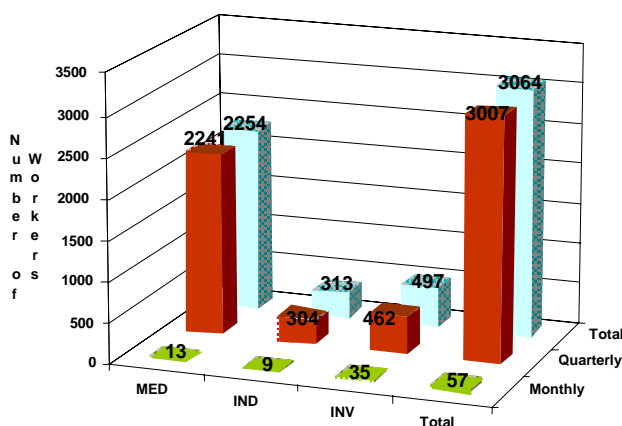


Fig. 1 – Number of monitored workers grouped by field of activity and monitoring period.

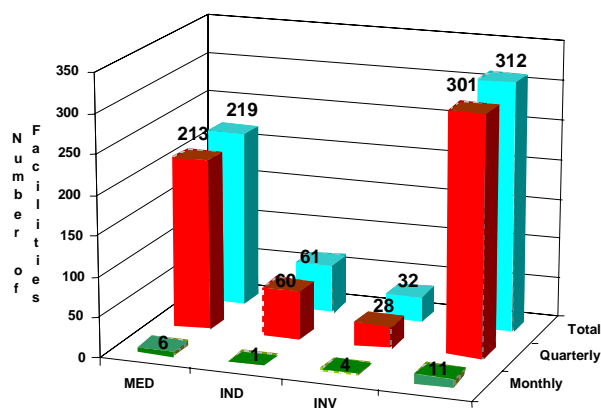


Fig. 2 – Number of facilities grouped by field of activity and monitoring period.

The distribution of the annual effective doses by dose intervals for the different fields of activity is presented in Figure 3. It can be seen that the annual doses are distributed in two intervals  $E < 0.5$  mSv (~93%) and  $0.5 \leq E < 5$  mSv (~6%). Annual doses exceeding 20 mSv were registered in less than 0.2% and the percentage of workers that received occupational doses higher than 10 mSv is approximately 0.7% of the total number of controlled workers.

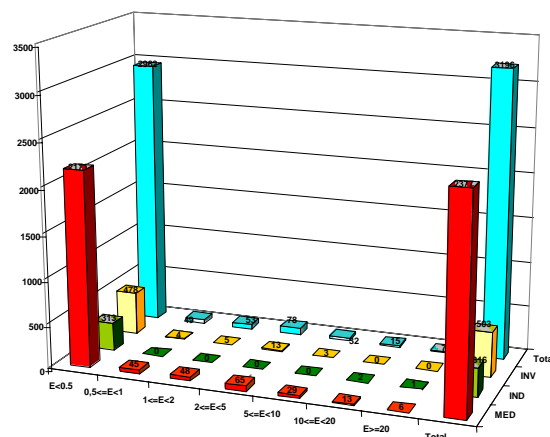


Fig. 3 – Distribution of the annual effective doses by dose intervals

#### Thermoluminescence dosimetry

J.G.Alves, E. Amaral, J.V. Monteiro, O.C. Margo, D.J. Miranda, S.B. Rosa, S.S. Rangel, R.A. Melo, R. Montezuma.

The TLD system is comprised of two 6600 Harshaw readers and on the Harshaw 8814 TL card and holder containing two  $LiF:Mg,Ti$  (TLD-100) detectors for the evaluation of  $H_p(10)$  and  $H_p(0.07)$ . Whole body doses are measured on a monthly or quarterly basis, for both systems.

The system allows the measurement of the operational quantities  $H_p(10)$  and  $H_p(0.07)$ , the personal dose equivalents at the depth of 10 and 0.07 mm, respectively.

In 2003, 6,800 workers from 744 facilities (aprox.) were controlled. The numbers of monitored workers distributed by fields of activity are presented in Figures 4 and 5.

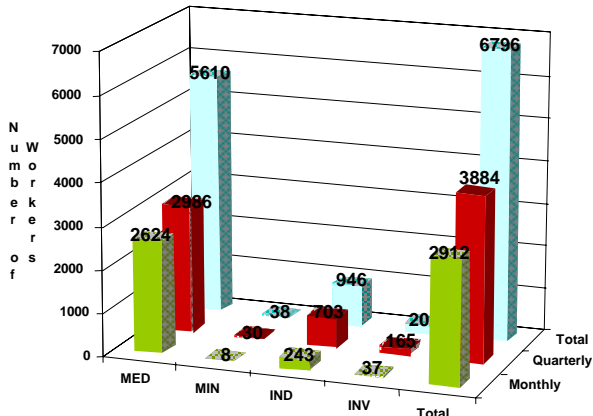


Fig. 4 – Number of monitored workers grouped by field of activity and monitoring period.

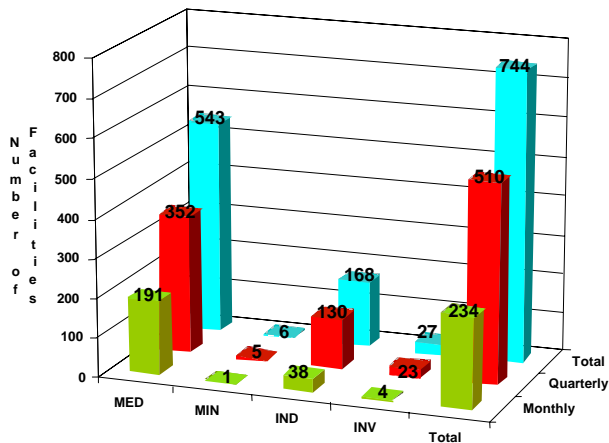


Fig. 5 – Number of facilities grouped by field of activity and monitoring period.

The distribution of the annual effective doses by dose intervals for the different fields of activity is presented in Figure 6. It can be seen that the annual doses are distributed in two intervals  $E < 0.5$  mSv (~84%) and  $0.5 \leq E < 5$  mSv (~13%). Annual doses exceeding 20 mSv were registered in less than 0.3% and the percentage of workers that received occupational doses higher than 10 mSv is approximately 1% of the total number of controlled workers.

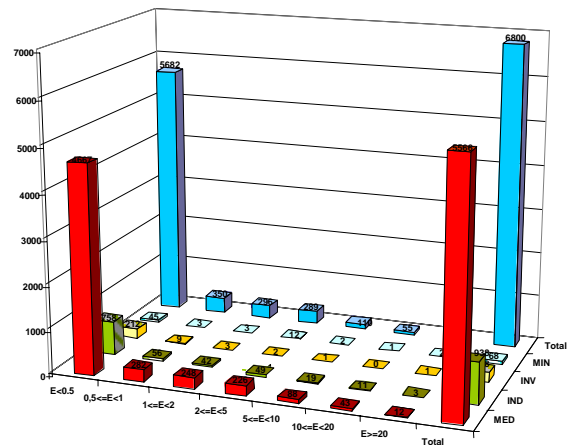


Fig. 6 – Distribution of the annual effective doses by dose intervals.

Using both Film dosimetry and TLD, 59,880 assessed doses (aprox.) were calculated. The total number of assessed doses and data for each monitoring period are displayed in Figure 7.

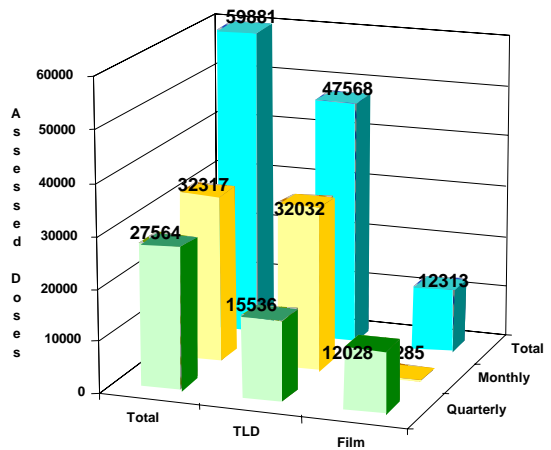


Fig. 7 – Total number of assessed doses in 2003.

## Radiobiology and Dosimetry by Cytogenetic Methods

### Specialized Cytogenetic Analyses

**J.H. Pereira Luís, O. Monteiro Gil, M. Luisa Pedro, R.G.V. Vieira add P.A.M. Cardoso**

During the year 2003 several specialized cytogenetic analysis were done. The analyses were used to identify biological damage at chromosomal

level induced by ionizing radiation or by other environmental aggressors. This type of analysis was also used to estimate the radiation dose by biological dosimetry.

Type of analysis	N° analyses
Chromosome aberration	3
Sister Chromatid exchange	4

## Radiological Safety Assessment

A.D. Oliveira, J.S. Jesus, Miguel Ângelo, M.E. Pacheco, Ana Maria Rosa

### Objectives

The main activity in this field is a technical service making reports in radiological safety assessment. Most of the services are requested by the General Directorate of Health of the Ministry of Health. Those reports are used for licensing radiological installations accordingly the national legislation. Nevertheless we make also inspection by direct request of the owners of the installations. Most of the activity in this field is services, but we make an effort to implement new methods, like the introduction of new software packages and stay up-to-date with the state of the art in radiation shielding and radiological assessment.

### Results

The results of this activity are hundreds of annual reports some of which having only a few pages and other are internal publications which are listed below.

### Published, accepted or in press work

- A.D. Oliveira, J. Sebastião and M. Ângelo, Verificação das condições de segurança radiológica de um equipamento de cobaltoterapia do Instituto de Radiologia – Dr. Idálio Oliveira, *Internal Report DPRSN-C*, nº 12/2003.
- A.D. Oliveira, J. Sebastião, K. Jacob and M. Ângelo, Verificação das condições de segurança radiológica de um Acelerador Linear Varian Clinac 2100C da Instalação IPOFG no Porto, *Internal Report DPRSN-C*, nº 10/2003.
- A.D. Oliveira, J. Sebastião and M. Ângelo, Verificação das condições de segurança radiológica de um Acelerador Linear Philips SL 75 do Instituto de Radiologia – Dr. Idálio Oliveira, *Internal Report DPRSN-C*, nº 11/2003.
- A.D. Oliveira, J. Sebastião and M. Ângelo, Estudo de segurança radiológica de um acelerador linear Clinac 2100C/D da Quadrantes - Clínica Médica e Diagnóstico, Sociedade Unipessoal, Lda, *Internal Report DPRSN-C*, nº 15/2003.
- A.D. Oliveira and M. Ângelo, Estudo de avaliação de segurança radiológica da instalação CMN – Centro de Medicina Nuclear S.A., *Internal Report DPRSN-C*, nº 18/2003.
- A.D. Oliveira and M. Ângelo, Estudo de avaliação de segurança radiológica da instalação de medicina nuclear da clínica Imacentro, *Internal Report DPRSN-C*, nº 6/2003.
- A.D. Oliveira and M. Ângelo, Estudo de avaliação de segurança radiológica da instalação de medicina nuclear da clínica CIMC, *Internal Report DPRSN-C*, nº 7/2003.
- A.D. Oliveira and J.S. Jesus, Avaliação de doses de radiação em radiologia de intervenção no centro hospitalar de Coimbra, *Internal Report DPRSN-C*, nº 16/2003.
- A.D. Oliveira and J.S. Jesus, Estimativa de doses de radiação em radiologia de intervenção no hospital N.S.R. – Barreiro, *Internal Report DPRSN-C*, nº 1/2003.
- A.D. Oliveira, Exposição de grávida em radiodiagnóstico no Diatra – Centro de Diagnóstico e Tratamento Médico, *Internal Report DPRSN-C*, nº 19/2003.
- A.D. Oliveira and L. Portugal, Suposta exposição a radiação durante a execução de trabalhos em tubagens de crude, *Internal Report DPRSN-C*, nº 14/2003.