Department of Radiological Protection and Nuclear Safety

Fernando da Piedade Carvalho

The Department of Radiological Protection and Nuclear Safety (DPRSN) of ITN is the only scientific department in the country with technical capability, experience and know-how in radiological protection. The department ensures the monitoring of radioactive contamination in food and environment, the monitoring of radioactivity in the uranium mining regions, the dosimetry of workers professionally exposed to radiation and radioisotopes, and the safety control of facilities, radiation emitting equipment and radioactive sources.

Research and Development

This Department of ITN primarily carries out research and development in the fields of:

- Environmental radioactivity
- Metrology of ionising radiations
- Dosimetry and biological effects of ionising radiations
- Safety of nuclear applications and radioactive waste management

The activities in the field of ***environmental radioactivity*** relate to the dispersal, behaviour and fate of radionuclides in the environment. In particular, for the radiological protection of the Portuguese population the research encompasses the study of radionuclides in terrestrial, aquatic and atmospheric environments, with special emphasis in the food chain transfer.

Metrological activities in the field of ionising radiations are carried out in the Metrological Laboratory of Ionising Radiation and Radioactivity (LMRI). The main objectives of LMRI are the following:

- keep the national standards and ensure their international traceability, under a contract with the Portuguese Institute of Quality;
- Research and development in the field of metrology and dosimetry of ionising radiation;
- Co-operation with EUROMET, AIEA and EA in the field of research, intercomparison of standards and accuracy of measurements. Co-operation in research activities of external teams through availability of irradiation beams and dosimetry;
- Technical services of metrological control (calibration, type testing, etc.) of measuring instruments.

Dosimetry and biological effects of ionising radiations brings together physical dosimetry of radiations and cytogenetic techniques for the same purpose. The main line of activity in physical radiation dosimetry concerns the evaluation of the radiation dose to the Portuguese population, and conceals both research and service activities.
Research activities in radiation dosimetry concealed both the development of Monte Carlo codes for photon interactions and the characterisation of thermoluminescent detectors for the low dose range with applications in environmental, individual, and medical dosimeters.

- Biological dosimetry measures the effects of radiation exposure on biological organisms. The goal of biodosimetry, when the exposure is known is to quantify how an exposure is distributed within an organism, or when the exposure is not known, assess the dose from observation of the organism.
- Exposure to ionising radiations may also induce genetic damage and biochemical modifications in tissues and at sub-cellular level which are investigated.

Safety of nuclear applications and radioactive waste management encompasses the radiologic risk assessment of facilities (radiation protection) and practices. Management of radioactive waste at national level is also ensured by the Department. Several routine activities such as the radiological surveillance of the ITN campus, and a number of services related to safety of nuclear applications, transport of radioactive materials, and radioactive waste management, were delivered.

Technical services

The Department provides to the country a wide variety of technical services. These services are often performed under contract with companies, under request from other Institutes or Government organisations, and in support to emergency action of Fire Brigades, Civil Protection and Customs.

Some of the more frequently asked services are:

- radioactivity analysis of water samples
- radioactivity analysis of goods and foodstuffs to export
- personal dosimetry of radiation workers from hospitals, clinics, industry, research institutions, etc.
- calibration of equipment used in medicine or industry to measure radiation
- measurement of radon in indoor atmosphere
- safety assessment of facilities and equipment producing or using radiation
- specialised medical control of radiation workers
- training of personnel in radiological protection.

Staff

Director: Fernando P. Carvalho

❑ Environmental Radioactivity

Researchers
- Fernando P. Carvalho (Aux. Researcher)
- Alfredo L. Mourão Brogueira (Aux. Researcher)
- Maria Carolina Vaz Carreiro (Princ. Researcher)[1]
- Maria da Conceição Faísca (Princ. Researcher)
- Maria José Madruga (Aux. Researcher)
- Mário C. Reis (Research Assistant)[2]
- José Alberto Corisco (Research Assistant)[2]

Technical Personnel
- Graciete Clemente Ferrador
- João Maria Mota Oliveira
- Maria Manuela Sequeira
- Albertina Libânio (from Nov./2000)
- Isabel Faria (**BSc** ITN grant)
- Helder Guerreiro (ITN grant)
- Sandra Curado (ITN grant)
- Victor Silvino (ITN grant)
- Rui Rodrigues (ITN grant) (since em 18/09/00)
- Rogério Rodrigues (left on 27/09/00)

Auxiliary Personnel
- Corália Gomes Costa
- Maria Amélia Pereira
- Maria dos Anjos Tavares

Students
- Carla Pires (**MSc** Student)
- Anabela Lucas (**MSc** Student)
- Pedro Duarte (**MSc** Student)
- Tânia Costa (**Last year BSc** student – Instituto Piaget, Almada)

❑ Metrology of Ionising Radiations

Researcher
- António M. Ferro de Carvalho (Princ. Researcher)

Students
- João Victor Cardoso (**MSc** Student)
- Luís Santos (ITN grant)
- Ana Filipa Quintino (left on Ago./2000)

❑ Dosimetry and Biological Effects of Ionising Radiations

Researchers
- Estela Maria Amaral (Aux. Researcher)
- João G. Alves (Aux. Researcher)
- José Pereira Luís (Princ. Researcher)
- Maria Berta Martins (Aux. Researcher)
- Maria Luisa Pedro (Aux. Researcher)
- Octávia Monteiro Gil (Aux. Researcher)
- Augusto D. Oliveira (Research Assistant)[2]

Medical Doctor
- José Eduardo Ribeiro e Costa

Technical Personnel
- Graciete Rangel
- José Sebastião Jesus
- Maria Adelaide Gameiro
- Maria Fernanda Fragoso
- Albertina Libânio (until Nov./2000)
- Ana Rafael Roda (ITN grant) (since 03/10/00)
- Lucília Madalena Montez (left on 30/09/00)
- Maria João Figueiredo (**BSc** ITN grant)

Auxiliary Personnel
- Alice Oliveira
- Helena Fonseca Santos
- João Paiva
- Maria Teresa Luzio
- Dulce Miranda (ITN grant)
- Paula Baptista (ITN grant) (Until Out./2000)
- Sandra Rangel (ITN grant)
- Susana Rosa (ITN grant)

Students
- Carlos Marcelino (**MSc** Student)
- Kátia Jacob (**MSc** Student)
- Vera Batel (**MSc** Student)

❑ Safety of Nuclear Applications and Radioactive Waste Management

Researchers
- Armando J. Severo[1] (Princ. Researcher)
- Maria Isabel Paiva (Aux. Research)
- Romão B. Trindade (Aux. Research)
- Rui Serro (Aux. Research)

Technical Personnel (Graduate)
- Luis Miguel Portugal

Auxiliary Personnel
- Artur Augusto Costa[1]
- Firmino Teixeira
- Francisco Barreira Gomes
- Ricardo Casquinha (ITN grant)
- Hugo Cordeiro (ITN grant) (left on Jun./2000)

[1] Retired during 2000.
[2] Doing PhD.

Administrative

- Ana Maria Rosa
- Dina Maria Alves
- Joaquina Monteiro
- Maria Emília Pacheco
- Maria Frederica Silveira

Driver

- Victor Cordeiro

Publications

Journals:	10	and 12 in press
Proceedings:	2	and 1 in press
Conf. Communications:	25	
Internal Reports:	20	
Theses:	2	

Funding

		$\times 10^3$ PTE
Research Projects:	**(a)**	11 077
Services:		71 687
TOTAL:		82 764

(a)

	$\times 10^3$ PTE
- Radionuclide Fluxes in Freshwater (Contact FI14-CT95-0018) (1996-2001) (731.916 EUROS → ITN/101.655 EUROS) Co-ordinator**:** Energy Research Foundation (ECN) Holanda,Partner: ITN (**Carolina Carreiro**)	2005
- Aquifers and Surface-Waters in the Chernobyl Area – Observations and Predictive Evaluation (Contract ERBIC 15-CT98-0205) (1998-2001) (243.972 EUROS → ITN/27.955 EUROS) Co-ordinator**:** Centre for Ecology end Hydrology (CEH) England, Partner: ITN (**Maria José Madruga**)	1377
- Site Survey of Radionuclide Station RN53, Azores, Portugal (Contract CTBTO-99-30-6034) (1999-2001) (ITN USD 36.000) ITN-Coordinator: **Fernando Carvalho**	7695
- Tropical and Sub-Tropical Cost-Effective Tools for an Integrated Risk Assessment of Wetlands (Contract UE IC18-CT98-0264) (1999-2001) (400.000 EUROS → ITN/80.000 EUROS) Co-Ordinator: Univ. Coimbra (Prof. Amadeu Soares), Partner: ITN (**Fernando Carvalho**), EPOMEX-México, Univ. Baía – Brasil	—

◈Environmental Radioactivity

Contamination of Coastal Lagoons in Tropical Regions

F.P. Carvalho, J.M. Oliveira, J.P. Villeneuve[1]

Objective

This international cooperative study funded by the European Union, aims at investigating the contamination of coastal lagoons in tropical environmental settings by anthropogenic pollutants, especially pesticides. Radionuclides are used as a tool for determining sedimentation rates and water mixing in the slow water-exchange environment of lagoons. Lagoon systems were investigated in Mexico, Laguna de Terminus, and in Brasil, Paraguaçu estuary and All-Saints Bay.

Results

Two field missions were carried out: during March in Laguna de Terminus and during October in All-Saints Bay. Missions were carried out in collaboration with counterparts from local Universities. A large number of water, sediment and biota samples was collected in each lagoon. Samples were pre-treated in-situ (filtration of water, radionuclide co-precipitation, pesticide extraction from water samples, slicing and freezing of sediment core layers, dissection of fish and oyster samples, etc.).

Analysis are in progress both in counterpart laboratories and at DPRSN, IAEA-MEL and DGA laboratories.

Preliminary results on pesticide residues in sediments from Laguna de Terminus indicate higher concentrations of DDTs and aroclors in stations located in the rivers. The concentrations of these persistent organic pollutants decrease seaward with higher dilution of riverborne discharges.

For example, concentrations of DDE (a break down product of DDT) in sediments ranged from 1.3 to 290 ng g^{-1} dry weight in sediments.

Distribution of organic contaminants in lagoon sediments indicates that the usage of these compounds in agriculture is the main source of contamination. Current levels are not excepcional in comparison with concentrations measured in coastal environments of other coastal lagoon systems [Carvalho, F.P., *et al., Arch. Environ. Contam. Toxicol.* **36** (1999) 132-139].

Concentration of ^{210}Po in oysters collected in the Terminus Lagoon indicate higher concentrations in the brackish water zone. This suggests that bioavailability of ^{210}Po in the water is reduced with the increasing load of suspended matter and humic substances observed in the freshwater and brackish water environment [Carvalho, F.P., Ramos, L.A., II, Conf. Nacional sobre a Qualidade do Ambiente, ed. Univ. Nova de Lisboa, 1990, pp.143-151].

Published (or in press) work

[1] Carvalho, F.P., González-Farias, F., Villeneuve, J.P., Cattini, C., Hernández-Garza, M., Mee, L.D., Fowler, S.W., Distribution, fate and effects of pesticide residue in tropical coastal lagoons of the Northwest of Mexico, *Environmental Technology*, in press.

Further Work

Analysis of persistent pesticides, pesticide concentrations in water and radionuclides in sediment will be completed [1]. The final results are expected to allow for a more complete interpretation of lagoon contamination and for improved environmental management of these coastal ecosystems.

[1] IAEA, Marine Environment Laboratory, Monaco

Aquifers and Surface-Waters in the Chernobyl Area- Observations and Predictive Evaluation

J. Smith[1], A. Konoplov[2], R. Comans[3], A. Kudelsky[4], G. Laptev[5], M.J. Madruga, G. Zibold[6], T. Costa[7], I. Faria, C. Costa

Objectives

The global objectives of this project are: to investigate long-term radiocaesium and radiostrontium dynamics in rivers, lakes and groundwaters; to develop simple, predictive, physically based and empirical models for prediction of long-term radiocaesium dynamics in these systems; to investigate the long-term dynamics of radiocaesium solid/water distribution in suspensions of soils, sediments and clay minerals as a function of the water phase chemical composition.

Results

In order to accomplish the objectives of the project a set of laboratory experiments of sediments characterization was carried out at the DPRSN, for sediments from Tejo river (Portugal) and Chernobyl contaminated areas (Belarus, Ukraine, Germany). The characterization consisted mainly on the determination of the frayed edge sites (FES) capacity and radiocaesium interception potential (RIP). For the FES determinations two methods have been used: the classical (Cremers method) and the Langmuir isotherms approaches. It is known that sorption isotherm with saturation is described by Langmuir Isotherms. The intercept of the dependence inverse concentration of caesium adsorbed on inverse concentration of caesium in solution, at high caesium concentrations, corresponds to the inverse value of FES capacity. Moreover taking the initial range of the isotherm, at low caesium concentrations, the capaciy of high affinity sites (HAS) can be calculated. The results for a set of sediments are presented in the next table.

It can be seen that FES values obtained from the Langmuir linearization are similar to those calculated from the radiocaesium isotherm plateau. The exchangeable RIP values in potassium and ammonium scenarios using ammonium acetate extraction are lower than the corresponding RIP [1-3].

A Licence Thesis in this subject is in progress at the DPRSN by a student (Tânia Costa) of the Instituto Piaget (Almada).

Communications

[1] Madruga, M.J. Radiocaesium distribution in Tejo river sediments: short-term prediction, *XVII Encontro Nacional da Sociedada Portuguesa de Química*, IST, Lisboa, 1-3 Março 2000.

[2] Konoplev, A., Smith, J., Comans, R., Kudelsky, A., Laptev, G., Madruga, M.J., Zibold, G. Aquífers and surface waters in the Chernobyl area: observations and predictive evaluation. *International Conference "Radioactivity after nuclear explosions and accidents"*, Moscow, Russia, 24-26 April 2000.

[3] Madruga, M.J., Faria, I. Determinação da capacidade específica de adsorção do radiocésio em sedimentos do rio Tejo, *XIV Encontro Luso-Galego de Química*, Universidade do Minho, Braga, 22-24 de Novembro 2000.

Further work

Radiocaesium extraction from sediments using two different protocols and long-term measurements of rates of radiocaesium sorption to sediment samples will be carried out.

Sediments	Cremers	Langmuir Isotherm		RIP_K	RIP_K (exch.)	RIP_{NH4}	RIP_{NH4} (exch.)
	[FES] meq kg^{-1}	[FES] meq kg^{-1}	[HAS] meq kg^{-1}	meq g^{-1}	meq g^{-1}	meq g^{-1}	meq g^{-1}
Lake Constance	2.49 ± 0.44	4.31	1.20	2.52	0.68	0.46	0.23
Lake Vorsee	1.13 ± 0.18	1.45	0.51	0.26	0.12	0.068	0.064
Lake Svyatoye [SV2 (C1-3)]	1.88 ± 0.02	2.49	0.38	0.83	0.42	0.23	0.15
[SVp2] (point 2)	5.47 ± 0.94	6.64	0.82	0.99	0.52	0.34	0.25
[SVp5] (point 5)	0.07 ± 0.01	0.12	0.03	0.085	0.030	0.021	0.007

[1]IFE (United Kingdom).
[2]SPA "Typhoon" (Russia).
[3]ECN (Netherlands).
[4]IGS (Belarus).
[5]UHMI (Ukraine).
[6]Fachhochschule-Weingarten (Germany).
[7]graduate student from Instituto Piaget, Almada, Portugal.

Environmental Impact of the Uranium Mill Tailings

M.J. Madruga, A. Brogueira, I. Faria, C. Pires, C. Costa

Objectives

The main objectives of this project is to evaluate the environmental impact of the natural radionuclides ^{226}Ra and ^{210}Pb from *Urgeiriça* uranium mill tailings in what concerns its dispersion in the environment and transfer to plants, that are growing in the tailings.

Results

During this year the ^{238}U, ^{226}Ra and ^{210}Pb activities of solid wastes, soils and plants (aerial part and roots) collected at the *Urgeiriça* mill tailings and surrounding area have been determined by gamma spectrometry. The distribution of these radionuclides at the oldest dams (more than 40 years old) show a great variability (by a factor of 5 to 10) of the ^{238}U, ^{226}Ra and ^{210}Pb concentrations at the surface tailings which indicates a heterogeneity of the radionuclides distribution at the dams area. It was observed a good correlation between ^{226}Ra and ^{210}Pb concentrations at the sampling site that presents lower ^{226}Ra concentrations [1, 2].
Exchangeable and total cations (K^+, Ca^{2+} and Mg^{2+}) have been determined in solid waste and plants samples by ionic chromatography.

Published (or in press) work

[1] Madruga, M.J., Brogueira, A., Alberto, G., Cardoso, F. Radium-226 bioavailability to plants at *Urgeiriça* uranium mill tailings. *Journal of Environmental Radioactivity*, in press.

[2] Madruga, M.J., Faria I., Brogueira, A. Spatial distribution of ^{238}U, ^{226}Ra and ^{210}Pb at Urgeiriça uranium mill tailings, *VII Jornadas Portuguesas de Protecção Contra Radiações*, Lisboa, 29 de Novembro 2000.

Further work

To calculate the ^{210}Pb soil/plant transfer factor and to correlate ^{226}Ra and ^{210}Pb soil/plant transfer factors with exchangeable and total cations (K^+, Ca^{2+} and Mg^{2+}) concentrations measured in solid waste and plants.
Geochemical characterization and contamination levels on the major and trace elements in particular, heavy metals associated with this mineralization area will be carried out at the Chemistry Department of the ITN (responsible M.F. Araújo). This study aim at the evaluation of the dispersal pathways and transfer mechanisms on the soil/plant system.
A large project related with the rehabilitation of old U-mining sites was submitted and approved by the IAEA. This will allow for expansion of the work started on radioactivity in mill tailings to a broader environmental scale. To be fully implemented next year.

Study of Aerosol Deposition Processes using Natural Radionuclides as Tracers

M.J. Reis, R.N. Rosa[1], A.O. Bettencourt, A.L. Brogueira

Objectives

The main purpose of this project is to study the atmospheric aerosol deposition processes (dry and wet) using natural radionuclides as tracers and its dynamics through the determination of size distributions, dry deposition velocities, scavenging coefficients and mean residence times.

Results

In the atmosphere, radioactive particles can either be directly emitted by anthropogenic sources or formed by the attachment of decay products of natural radioactivity to existing particles. Natural radionuclides participate in the formation and growth of the accumulation mode aerosol, allowing their use as natural tracers for aerosol transport and deposition processes.

On this aim, the studied radionuclides were the radon and thoron short-lived decay products ^{214}Pb and ^{212}Pb, the long-lived radon daughter ^{210}Pb and the cosmogenic ^{7}Be. Aerodynamic size distribution measurements were carried out and indicates that all those radionuclides are associated with aerosol particles in the accumulation mode. ^{210}Pb and ^{7}Be were found to be attached to submicron-sized aerosol (activity median aerodynamic diameter of 0.47 μm for ^{210}Pb and 0.54 μm for ^{7}Be). The short-lived ^{214}Pb and ^{212}Pb were found to be associated with smaller aerosol particles (activity median aerodynamic diameter of 0.21 μm and 0.18 μm, respectively). On average, it was observed that about 80% of the ^{214}Pb and ^{212}Pb activity was associated aerosol particles with aerodynamic diameter smaller than 0.49 μm and about 90% with particles smaller then 0.95 μm.

The preferential attachment of ^{214}Pb and ^{212}Pb to smaller aerosol particles, together with their short half-lives make them suitable natural radioactive tracers in studying the dry deposition processes of submicronic atmospheric aerosols. Since the referred radionuclides have a finite life, their presence on a surface (for example vegetation) represents a finite deposition history. Therefore, the dry deposition velocities were evaluated by relating the concentrations on vegetation of the chosen radionuclides to their ambient air concentrations.

Air concentrations of ^{7}Be and ^{210}Pb were also monitored in order to determine the aerosol carrying air masses origin and transport history, by calculating the activity ratios and radioactive loading indexes.

All the samples activity was measured by γ-ray spectrometry using both coaxial and low-background well-type HPGe detectors.

Published (or in press) work

[1] Reis, M.J., Rosa, R.N., Bettencourt, A.O., Brogueira, A.L., Size Distributions of Short-Lived Radon and Thoron Daughters and Cosmogenic ^{7}Be Associated with Aerosols in the Surface Air at Sacavém (Lisbon), *Journal of Atmospheric Chemistry*, in press.

[2] Reis, M.J., Brogueira, A.L., Rosa, R.N., Bettencourt, A.O., Low-level Atmospheric Aerosols Radioactivity Measurements, *VII Jornadas Portuguesas de Protecção Contra Radiações*, Novembro de 2000.

Further work

Investigation of the short-term effect of rainfall on activity composition and size distribution of atmospheric aerosols will be carried out. Collection of fog water will also be attempted in order to compare the efficiency of different wet removal processes.

[1]Physics Department of Évora University.

Transport Mechanisms of Radiocesium and Radiostrontium by the Microalgae *Chlamydomonas reinhardtii* Dangeard

J. A. Corisco, J. Fernandez[1], F. Carvalho

In the framework of this PhD project a series of experiments was performed according to the following items:

1. Biovolume changes in *C.reinhardtii* batch cultures, submited to a wide range of external potasium concentrations. This was a vertical/horizontal study in order to know how algal cells change their volume in time under different potassium treatments. Basically algae were cultivated under a low range of micromolar K^+ and a high range of milimolar K^+. Measures of volume with an image analiser were made during a period of aproximately one week and statistical parameters were calculated. Biovolume data will be used to correct all previous results obtained through radiometric measurement of ^{137}Cs which were still referred to number of individual cells. The expression of radioactivity in phytoplancton as a function of total biovolume is the finest approach when it comes to a) measure concentration factors of radioisotopes and b) compare radioisotope uptake rates under different treatments of a variable (pH, K^+, temperature, etc.) that might affect the dimension of cells and the pattern of volume distribution.

2. Uptake and accumulation of ^{90}Sr by C.reinhardtii, under different external Ca^{2+} treatments, with algae adapted to deficiency and sufficiency of K^+. The first objective was to know how uptake rates and concentration factors of ^{90}Sr are affected by external Ca^{2+} concentration to verify the hypothesis that the radioisotope is entering the cells through the specific Ca^{2+} channels. If its true, than increasing external Ca^{2+}, will cause a decrease in both uptake rates and concentration factors. The second objective was to know if ^{90}Sr might also enter through K^+ difusive pathways, it means, through K^+ channels. This plasmalema channels are known to be activated in plants surrounded by a non limiting K^+ environment. Plants in this situation are said to be adapted to K^+ sufficiency. If external K^+ is limiting, channels are closed and plants adapt to K^+ deficiency, by expressing a secondary active uptake mechanism. It has been shown that in the aquatic plant *Riccia fluitans*, that active mechanism also serves for ^{137}Cs uptake. Results previously obtained during 1998/99 with *C.reinhardtii* are coherent with the hipothesis that these algae also exhibit an active mechanism of $K^+/^{137}Cs^+$ uptake regulated by pH (to be further submited). So, the aim was to verify if that , under K^+ deficiency (K^+ channels closed), ^{90}Sr uptake in *C.reinhardtii* is affected or not.

3. Strontium uptake kinetics by *C.reinhardtii*, under different external Ca^{2+} treatments, with algae addapted to K+ defficiency. Ion kinetics must be understood as the changes in uptake rate as a function of its concentration in the external medium. Kinetics gives fundamental information about the affinity of the transport system of the ion under study in a test organism. In simple terms, an ion channel has been formerly understood as a transport system with low affinity and linear kinetics. On the contrary, an active transport system must exhibit saturated kinetics and its affinity for the ion must be high . This was verified formerly for ^{137}Cs with *C.reinhardtii*. . The objective of this task is to verify the hypothesis that ^{90}Sr is entering algal cells through Ca^{2+} channels and how does the external concentration of the major cation affect the uptake and accumulation of the radioisotope. Working with algae adapted to K^+ deficiency prevents the possibility that some ^{90}Sr might enter the cells through K^+ channels, creating an experimental artefact. Several Ca^{2+} external concentrations are going to be tested. Till this date work has been done with 0.1mM Ca^{2+} and its expected to perform a couple of experiments more with 1mM and 10mM Ca^{2+}.

4. Effect of external pH on the uptake and accumulation of ^{90}Sr by *C. reinhardtii*. This work has been done with algae adapted to K^+ deficiency and an external concentration of 1mM Ca^{2+}. The objective was to verify the hypothesis of pH control on the uptake and accumulation of the radioisotope.

Concerning these studies two papers are under preparation.

Further work

The study of the external Ca^{2+} effect in uptake and accumulation of ^{137}Cs and the uptake kinetics of ^{90}Sr by *C. reinhardtii* will be performed during 2001.

[1] Facultad de Ciencias, Universidad de Málaga (Spain)

On-site Study for Installation of an Aerosol Monitoring Station in Azores

F.P. Carvalho, J.M. Oliveira, A.M. Brogueira, E. Amaral, M. Reis, C. Pires

Objective

This project aimed at selecting a suitable site for installation of a continuous air monitoring station in S. Miguel island, Azores. This station will be part of the international monitoring system agreed upon by the States under the Comprehensive Nuclear Test-ban Treaty.

Results

Two field missions were carried out in the island of S. Miguel to perform aerosol sampling, in-situ gamma ray spectrometry, environmental radiation dose measurements and collection of soil samples. Four sites were retained for a deeper investigation of the radiation levels, and by the end of the study, one site was selected as the most suitable for installation of the radionuclide station. Radioactivity levels are generally low in the island (Table 1) but other factors such as exposure to winds, rainfall and availability of power supply, are also taken into account in selecting the site for the station.

A final report was submitted to the Technical Secretariat of CTBTO. The report and the station were approved.

Internal Report

[1] Carvalho, F.P., Oliveira, J.M., Brogueira, A., Amaral, E., Reis, M., Pires, C., Site Survey For Installation of Station RN53, Azores, Portugal, Final Report Contract Nº. CTBTO/99/30/6034, 15 Março 2000.

Further work

The construction of the infrastructure and installation of the radioanuclide measuring equipment will be contracted during 2001. This will be followed by extensive testing, calibration and international intercalibration of the equipment performance.

Table 1. Concentrations, Bq kg^{-1} dry weight of naturally-occurring alpha emitting radionuclides in soil samples from S. Miguel, Azores, collected in Spring 2000.

Site	^{238}U	^{235}U	^{234}U	^{232}Th
1. Nordela	57±2	3.2±0.4	54±2	NA
2. Airport	57±3	3.7±0.5	56±3	48±6
3. Chã de Macela	70±3	4.4±0.5	71±3	64±12
4. Pico da Cruz	68±3	3.5±0.4	68±3	61±6

NA = not analysed.

Radioactivity in Spring Waters and Surface Waters for Human Consumption

G. Ferrador, C. Faísca, S. Curado, F.P. Carvalho

Objectives

This project aims at determining naturally-occurring radionuclides in waters from spring sources and surface waters used for human consumption both as drinking water and cooking water. The results are expected to provide a better insight in radioactivity of natural waters and to allow for enhanced radiation protection of the population.

Results

Today, most of the water supplied to the portuguese population comes from surface reservoirs. Only a few supplies and bottled mineral waters originate in underground sources.
Waters distributed in OPorto and Lisbon areas are currently investigated for radionuclide concentrations. Mineral waters from various sources are also being investigated for full characterization of radionuclide concentration. Some of these waters have relatively high levels of radon, and radon progeny which are the main contributors to the total alfa-activity (Table 1). Preliminary results indicate that a more systematic and comprehensive review of the radiation dose through consumption of water from public supplies is needed. Furthermore, some water reservoirs are located in catchment areas exposed to contamination by uranium mining or by nuclear power plants located abroad. This is a matter of additional concern.

Internal Reports

[1] Carvalho, F.P., A Radioactividade e a Água que os Portugueses Bebem. Memorando ITN-DPSRN, 10 págs. Dez. 2000.

[2] Carvalho, F.P., Parâmetros Radiológicos, Considerações para a Transposição da Directiva 98/83/CE relativa à qualidade da água para consumo humano. Memorando ITN-DPRSN preparado para o IRAR, 5 págs. , 2 Outubro 2000.

Further work

Full characterization of mineral waters for radioactivity contents is planned. This will be carried out in conjunction with the Geological Survey and the Industry Association of Mineral Waters during 2001-2002. A project has been submitted for funding by this sector of the economy.
Surface water reservoirs and the risk of radiological contamination has been considered in the preparation of regulations, to be enforced soon, on the quality of water for human consumption.

Table 1. Radioactivity in water from public supplies and spring sources (mBq L^{-1}). Some examples.

Water	Total Alfa radioactivity	Total Beta radioactivity	Radium-226
Lisbon	22 ± 1	142 ± 19	---
Oporto	21 ± 7	179 ± 35	---
Spring water (i)	---	1035 ± 43	940 ± 43
Spring water (ii)	---	100 ± 42	≤ 5
Spring water (iii)	---	51 ± 1	14 ± 4

Radon in Houses and Construction Materials

C. Faísca, P. Duarte, F.P. Carvalho

Objective

Determination of radon levels in houses build up both with traditional materials and modern materials. This project stems in work previously carried out by the Department, namely indoor radon mapping country wide. This new phase aims at investigating deeper some specific radon prone areas, to improve awareness and radon mitigation measures.

Results

A project on measurement of radon in houses in granitic and limestone areas of Portugal was started with funding provided by a non-governmental organization. Passive radon detectors were made up and distributed for exposure in family houses.
The results of the project and a report will be issued in the last quarter of 2001. The results will allow for advice on countermeasures eventually needed.
A project proposal for a Concerted Action to be funded by EU was prepared (ERRICA 2). This European wide project aims at improving awareness in countries about the radon exposure.
An agreement with the National Laboratory of Civil Engineering (LNEC) was reached to cooperate in the investigation of radioactivity in construction materials and to implement protection measures within new buildings, and to advise radon mitigation work in existing buildings (houses).

Results of the analysis of various building materials indicate that some materials may contain relatively high ^{226}Ra concentrations which, in turn, originate high radon exahalation rates (Table 1) [Faísca, C., Teixeira, R., *Proceedings of an Int. Conf. on Radon in the Living Environment*, Atenas, 1999, pp.935-942].

Further Work

Implementation of the agreement reached with LNEC on the research of radioactivity in construction materials. Publication of a report on radon in houses.

Table 1– Natural radioactivity in some construction materials.

Material Sample	Specific activities ($Bq.kg^{-1}$)			^{222}Rn exhalation ($mBq.m^{-2}.s^{-1}$)
	^{226}Ra	^{232}Th	^{40}K	
sand (32)	2-202	4-161	123-2140	0.1-34
cement (7)	21-59	11-34	220-250	0.5-0.9
brick (10)	37-90	31-72	473-1098	0.5-2.9
gravel (11)	10-130	2-56	190-569	0.1-1.9
gypsum (16)	4-705	2-12	2-90	0.1-21
concrete block (11)	8-98	7-86	278-529	0.3-3.6

(n) number of samples analysed

Monitoring Programmes

A) Artificial Radioactivity in the Tejo and Zêzere Rivers

A.Brogueira, M.M.Sequeira, M.A.Pereira, C. Pires, V. Silvino

Objective

To perform a survey of the artificial and also the natural radioactivity in Tejo River, as some nuclear installations exist upstream in Spain, and in Zêzere river, which does not suffer such an influence and serves as a background to Tejo river.

Results

Monthly sampling of water, sediments, hydrophytes and fish are carried out at three stations in Tejo river (Vila Velha de Rodão, Fratel dam and Valada do Ribatejo). Monthly sampling of water is also carried out at Castelo do Bode in Zêzere river. At Fratel and Sacavém rain water is also sampled.
^{137}Cs is usually detected in all compartments of the river ecosystems; ^{90}Sr and ^{3}H are only measured in river and rain water.
Natural radioactivity (^{226}Ra, ^{228}Ra, ^{235}U) is measured in sediments, hydrophytes and fish.
Radiochemical analyses of river water are carried out in 40 liter of 0.45 μm filtered samples. Methods for ^{137}Cs, ^{90}Sr and ^{3}H radiochemical analyses are described in previous papers. River bank sediments, after drying, are subjected to quantitative gamma-spectrometry on the whole sediment and on the fractions ≤ 212 μm and ≤ 75 μm. Fish and hydrophytes from the most common species at the sampling stations are dried, ashed and gamma analysed.
Beta radioactivity measurements are performed in a low-background gas flow counter. Tritium is measured by liquid scintillation. Gamma-spectrometry is carried out on a Ge detector coupled to a 4000 channel analyser.

In the framework of the Regional Programme of Research and Technological Development of Extremadura Commission (Spain) a collaborative programme between the ITN/DPRSN and the Departamento de Física da Faculdade de Veterinária (Universidade de Extremadura) was carried out that focus on research of radionuclides (^{90}Sr and ^{137}Cs) transport mechanisms in sediments and water, concerning Arrocampo (cooling pond of Almaraz NPP), and the dams of Arrocampo, Torrejon, Alcantara and Cedillo in Spanish part of Tejo river and Vila Velha de Rodão, Fratel dam and Valada do Ribatejo in the Portuguese part. Intercomparison of methods and results was performed.
Four intercomparison exercises were accomplished and one meeting (in Sacavém) was held for discussions.
One joint paper was presented to the 26ª Reunión Annual de la Sociedad Nuclear Española, León, 4-6 October 2000.

Published (or in press) work

[1] Sequeira, M.M., Brogueira, A., Pires, C. Carreiro, M. C. . Radioactividade Medida nos Rios Tejo e Zêzere, em 1999. *Relatório DPRSN-A* nº1, 2000.

[2] Baeza, A., Brogueira, A., Carreiro, M. C., Garcia, E., Miró C., Gil, J.M., Sequeira, M.M., Teixeira, M.M. Spatial and Temporal Evolution of the Levels of Tritium in the Tagus River in its Passage Through Extremadura (Spain) and the Alentejo (Portugal). *Water Research*, in press.

Further work

This radiological survey (initiated in 1976 in Tejo river and in 1990 in Zêzere river) must be carried out every year. The collaborative programme with the Departamento de Física da Faculdade de Veterinária (Universidade de Extremadura) is foreseen until 2001.

B) Radiological Surveillance of the River Águeda and Mondego in Relationship with Uranium Mining Activities

J. M. Oliveira, M. M. Sequeira, A. Brogueira, M. A. Pereira,
M. A. Tavares, C. Pires, V. Silvino

Objective

The effluents of uranium mines and facilities of uranium milling are directly discharged into the river Mondego and Águeda. The eventual radioactive contamination of the rivers may occur through accumulation of uranium and thorium, which are the most significant radionuclides in the uranium extraction.

Results

During this year, samples of water, suspended matter, sediments and fish were collected twice a year, in several sampling points in both rivers. The concentrations of ^{226}Ra and uranium were determined by alpha spectrometry in all samples. In sediments, ^{226}Ra activity was also determined by gamma spectrometry.

In Águeda river, the analysis of uranium in water was always 4 times higher than in the water of the river Coa, which was selected as an environmental reference.
So far, in the river Mondego there has not been recorded any increment of the natural ^{226}Ra and uranium levels which could be attributed to the uranium mining.

Further work

The radiological surveillance of these rivers will be continued.

C) Environmental Survey Network

M. C. Faisca, M. M. Sequeira, G. Ferrador, A. Brogueira,
C. Pires, S. Curado, M. A. Tavares

The Department carried out a national programme for the monitoring of radioactivity in superficial and drinking waters, milk and mixed diet. Samples are regularly collected from different regions of the country, accordingly with international sampling procedures, and analysed in the laboratory for the concentration of artificial radionuclides.
This programme has been designed in accordance with the European network for environmental radioactivity, following the requirements of Art.º 35º and Art.º 36º of the EURATOM Treaty. All data are therefore formatted accordingly with the *Easy Proteo Input Processor,* and sent to the EU Joint Research Centre, Ispra, where they are introduced into the European Database.

In the field of the monitoring programmes a MSc Thesis has been performed by C. Pires concerning the determination of the spectrometry gamma systems efficiency using numeric methods and its application to the study of samples in the framework of the environmental radioactivity.

◈Metrology of Ionising Radiations

Harmonisation and Dosimetric Quality Assurance in Individual Monitoring for External Radiation - EURADOS Action Group -

P. Ambrosi[1], C. Back[2], D.T. Bartlett[3], J.M. Bordy[4], P. Christensen[5], T. Colgan[6], A.F. de Carvalho[7], A. Delgado[8], J. W .E. van Dijk[9], E. Fantuzzi[10], H. Hyvonen[11], L. Lindborg[12],H. Stadtmann[13], F. Vanhavere[14], C. Wern1i[15] M. Zamani-Valasiadou[16]

Objectives

The current status within EU Member States and Switzerland were examined in what concerns the requirements for approved dosimetric services. The present situation amongst Member States is that there are widely differing national requirements for the performance of dosimetric services and dosemeters. It is clear that with the free movement of workers within the EU and the multinational ownership of companies. a degree of harmonisation of requirements and procedures would be desirable. The study aims to assist harmonisation. by giving the current status of procedures and requirements in Member States and Switzerland thereby allowing comparisons to be made.

RESULTS

Technical requirements for approved dosimetric services were listed and examined in EU Member States and Switzerland. The EURADOS Action Group recommends as a first step towards harmonisation that it would be helpful if there were periodic performance tests or intercomparison exercices within European Union.

Data reported shows that quality assurance programmes are not general practice and that in some countries the doses are not assessed in terms of $H_p(d)$. Useful information was prepared to assist those services in the implementation of new quantities.
Results of an intercomparison of dosimetric services shows good results for photon dosemeters and a large number of results for beta and neutron dosemeters underestimating personal dose equivalent [1].

Published work

[1] Report of European Radiation Dosimetry Group (EURADOS), *Radiation Protection Dosimetry* **89** (1-2) (2000) 1-154.

(1) Physikalisch-Technische Bundesanstalt, PO Box 3345, D-38023 Braunschweig
(2) Division de Ia Radioprotection, Villa Louvigny -Allée Marconi, L-120, Luxembourg
(3) National Radiological Protection Board. Chilton. Oxon, OX11 ORQ, United Kingdom
(4) IPSN-DPEA-SEC, BP No.6, F-92265. CE Fontenay-aux-Roses, France
(5) Riso National Laboratory. PO Box 49, DK-4000 Roskilde, Denmark
(6) Radiological Protection Institute of Ireland, 3 Clonskeagh Square, Dublin 14, Ireland
(7) ITN -Dep. of Radiological Protection and Nuclear Safety, Estrada Nacional 10, P-2686-953 Sacavem, Portugal
(8) CIEMAT, Avenida Complutense 22, E-28040 Madrid, Spain
(9) NRG- Arnhem, Utrechtseweg 310, Postbus 9034,6800 AS Arnhem, Netherlands
(10) ENEA -Ente Nazionale per le Nuove Tecnologie, l'Energia e I' Ambiente -Istituto per la Radioprotezione, :Via dei Colli 16, 1-40136 Bologna, Italy
(11) STUK, Radiation and Nuclear Safety Authority, PO Box 14, FIN 00881 Helsinki. Finland
(12) Swedish Radiation Protection Institute, *SSI, S-17116* Stockholm, Sweden
(13) Austrian Research Centre Seibersdorf, A-2444 Seibersdorf, Austria
(14) SCK-CEN, Boeretang 200. B-2400 Mo1, Belgium
(15) Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland
(16) AUT-Greece Nucl. Phys. Laboratory, Aristotle University of Thessaloniki, GR-54006 Thessaloniki, Greece

◈ Dosimetry and Biological Effects of Ionising Radiations

Study of LiF:Mg,Cu,P and LiF:Mg,Ti Detectors on the Low Gamma Dose Range: Thermal Stability and Limits of Detection

J.G. Alves, A. Delgado[1], M. Secca[2], E.M. Amaral, J.L. Muñiz[1], J.M. Gómez Ros[1]

Objectives

This work aimed at the study of two of the most important characteristics of LiF:Mg,Ti (TLD-100) and LiF:Mg,Cu,P (GR-200) when used in the fields of Environmental and Personal Dosimetries, the low gamma dose range.
The characterisation of the thermal stability of GR-200 compared to the classical TLD-100, taken as reference was accomplished. The experimental evaluation of the limits of detection and of determination of the dosimetry system based on these two materials was also carried out. Computerised glow curve analysis methods (GCA) and conventional methods were used in the course of this work.

Results

LiF:Mg,Ti (TLD-100) and LiF:Mg,Cu,P (GR-200) are two well known thermoluminescent materials used in the Dosimetry of ionising radiation.
Thermal stability was studied by storing samples of both materials, both irradiated and unirradiated, in laboratory controlled conditions at 40ºC and 70ºC, for storage periods that varied from 6 hours to 24 days. The results show that GR-200 is far more stable than TLD-100 for the two temperatures studied, and that the migration and aggregation of the impurities based defects structure altering the trap system, are the main cause of the sensitivity changes observed. Thermal fading, understood as the spontaneous release of the trapped charges, does not influence the behaviour of the main peaks, in both materials.
The limits of detection and of determination were studied starting from Currie and Hirning's well known expressions, originally deduced for the conventional analysis of the glow curves. All curves were analysed with the conventional and the simplified analysis method (SGCA). The results show that SGCA always provides better results than the conventional method, and allow the estimate of a detection threshold for the detectors and for the measurement system used. 10 μGy and 1 μGy were estimated as the detection threshold, for TLD-100 and GR-200, respectively, analysed with SGCA.
This work was part of a PhD Thesis presented and discussed at the Universidade Nova de Lisboa in June 2000.

Published (or in press) work

[1] Muñiz, J.L., Alves, J.G., Delgado, A., Gómez Ros, J.M., Mejoras en la Medida de Dosis con LiF:Mg,Cu,P por el uso de Métodos de Análisis por Ordenador de la Curva de Termoluminiscencia, *VII Congreso Nacional de la Sociedad Española de Proteccion Radiológica, Maspalomas*, Gran Canaria, Spain, September 2000, *Radioprotección*, in press.

[2] Alves, J.G., Muñiz, J.L., Gómez Ros, J.M., Delgado, A., Estudo dos Detectores Termoluminescentes LiF:Mg,Ti e LiF:Mg,Cu,P para Baixas Doses de Radiação Gama: I. Estabilidade Térmica, *Jornadas da Sociedade Portuguesa de Protecção Contra Radiações*, Lisboa, November 2000, *Radioprotecção*, in press.

Further work

This work was part of a PhD Thesis that was presented and discussed at the Fac. de Ciências e Tecnologia of the Universidade Nova de Lisboa.
As a continuation of this work, an optimization of the dose evaluation procedure used in individual monitoring of external radiation is expected.

[1] CIEMAT – Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid, Spain.
[2] Dep. Física, Fac. de Ciências e Tecnologia da Univ. Nova de Lisboa (PhD supervisor along with A. Delgado).

Analysis of the Individual Monitoring of External Radiation Data

J.G. Alves, M.B. Martins, E.M. Amaral

Objectives

This work aims at the analysis of the occupational radiation doses for external exposure received by the radiation workers monitored by the Radiological Protection and Nuclear Safety Department (DPRSN).

Results

The individual monitoring for external radiation is performed at DPRSN using two dosimetric systems, one based on film (since the 60's) and the other one based on thermoluminescent detectors (since 1996). All the workers monitored by DPRSN are controlled with respect to X and gamma radiation using whole body dosemeters worn on the trunk, in the position of likely maximum exposure.

DPRSN monitors approximately 8400 persons from 790 facilities spread from all over the country. Occupational exposure arises from four different fields of activity, namely, conventional industry (IND), research laboratories (RES), health or medicine (MED) and mining (MIN). Since there are no nuclear power plants in the country persons monitored at ITN have been included in the research group.

Annual effective doses measured with film became available on data base records recently. Previously reported data (from 1991 onwards) that were registered on paper were gradually introduced in data base format.

The annual effective dose measured in the years 1994 to 1999 with either method was determined and analysed. The results obtained for the IND, RES and MED fields present a typical pattern: a very high bar ≈80% for the E<0.5 mSv dose interval, a decreasing tail with the most significant portion contained in the dose values [0.50, 6[mSv, followed by negligible values afterwards (1,2). The dose distribution for the mining sector also presents a similar pattern but different from the above: nearly 35% were not exposed, 50% were contained in the [0.50, 6[mSv interval, while 14.7% exceeded 6 mSv, but no one exceeded 15 mSv (1,2).

In 1999 none of the exposed persons received doses higher than the annual dose limit of 50 mSv, and it was observed that 0.5% (IND) and 0.7% (MED) exceeded 15 mSv. If an annual limit of 20 mSv is considered, only 0.1% (IND) and 0.4% (MED) of the monitored population exceeded this value (1,2).

It may be inferred that the results measured in the 1994-98 period (1) and in 1999 (2) seem to comply with a possible future limit of 20 mSv and its 3/10ths (6 mSv).

Annual mean effective doses for the monitored and exposed populations were calculated (1,2). The collective dose data for the same period was estimated and is presented in Table 1. It can be observed that the increase in the 1994 to 1999 period is due to the medical contribution to the total collective dose.

Published (or in press) work

[1] Alves, J.G., Martins, M.B, Amaral, E.M. *Occupational Radiation Doses in Portugal from 1994 to 1998*. Proceedings of the IRPA-10, the *10th International Congress of the International Radiological Protection Association*, Hiroshima, Japan, May 2000, P-3b-174, 1-9 (2000).

[2] Alves, J.G., Martins, M.B, Amaral, E.M. *Occupational Exposure in Portugal in 1999*. Proceedings of the European Workshop on Individual Monitoring of External Radiation, Helsinki, Finland, September 2000, P-2, (2000). *Radiat. Prot. Dosim.*, in press.

Further work

The results obtained for the medical field recommend a closer review of the data to identify the type of work (professions) and of practices that give rise to the higher doses.

An evaluation of the 1991 – 1993 annual effective doses is being prepared along with a reassessment of the reported results for the 1991 – 2000 period at the light of the UE Directive 96/29/EURATOM.

Table 1: Collective dose for the years 1994 to 1999 (man.Sv)

Working field	1994	1995	1996	1997	1998	1999
IND	0.30	0.20	0.28	0.50	0.52	0.53
RES	0.23	0.15	0.02	0.01	0.01	0.02
MED	2.02	2.11	2.04	2.48	2.97	3.99
MIN	0.08	0.11	0.02	0.03	0.08	0.20
Total	2.62	2.57	2.36	3.02	3.57	4.74

Computer Methods in Radiation Protection: Computational Dosimetry for Photon Energies in the Range 10 – 150 keV[1]

A.D. Oliveira, J.J. Pedroso de Lima[2], E.M. Amaral

Objectives

This work is an application of the Monte Carlo method in radiation protection. The main object of study is the set of points of energy deposition due to the interactions of the radiation with matter.

Results

We discuss some modern topics of the research in this field. In this sense we suggest that the radiological protection is an application of the radiation biophysics instead of the radiation physics. We developed and implemented a photon Monte Carlo codes for low energy range 10-150 keV. We have made a careful verification of the code, testing and comparisons with results from other codes. We studied the spatial structure of the set of points of energy deposition using a new method of analysis designated dynamic analysis. For the first time we introduced the concept of entropy as a tool in radiation physics allowing the description of the degradation of the energy of the primary photons. We pointed out the close relation with the quality factor and the simplicity of the entropy approach. Transmission, deposition and back scattering of the energy of the radiation beam are usual parameters used in radiation physics. We obtained results for those parameters and presented new insights in medical applications of the radiation. In computed tomography we presented new methods of simulation. The convergence of the simulations is an important topic in computational dosimetry. The analysis of the convergence is a complex task and we contributed with an approach leading to the decreasing of the error presented in usual results of simulations. The graphical 3D representation of points in space is also one important topic. We implemented a routine using parallel perspective to represent 3D data in a 2D plane.

Communications and Proceedings

[1] Oliveira, A.D. and Pedroso de Lima, J. J., Dynamical analysis of data, Presented at the *5th Portuguese Conf. on Biomedical Engineering*, Coimbra, May (2000).

[2] Oliveira, A.D. and Pedroso de Lima, J. J., Parallel perspective representation of three-dimensional points, Presented at the *5th Portuguese Conf. on Biomedical Engineering*, Coimbra, May (2000).

[3] Oliveira, A.D. and Pedroso de Lima, J. J., The degradation of the energy of primary photons described through the entropy, *Proceedings of the International Conference on Advanced Monte Carlo for Radiation Physics, Particle Transport Simulation and Applications - MC2000*, Lisbon, 23-26 Oct. 2000, eds. A. Kling, F. Barão, M. Nakagawa, L. Távora, P. Vaz, Springer Verlag, Berlin, Heidelberg, in press.

[4] Oliveira, A.D. and Pedroso de Lima, J. J., The spatial structure of photons scattered in water, *Topical Meeting in Medical Radiation Physics and Engineering - TM-MERPE2000*, Fundação Calouste Gulbenkian, Lisbon, 20-22 November 2000.

[5] Oliveira, A.D. O Método de Monte Carlo para Fotões de Energia entre 10 e 150 keV, *VII Jornadas Portuguesas de Protecção Contra Radiações*, Lisboa, 29 November 2000.

Further work

We study the interaction of radiation in non-homogeneous materials from the point of view of computational simulation. Our objective is to implement a new code for a non-homogeneous medium and compare with other results. Application to radiation protection is a primary goal. Starting from the existent codes, for homogeneous materials, we intended to increase its capacity with new routines. Emphasis will be given to fluorescence X-ray photons and to the interface between two different media and also to higher values of the photon energies. Application will be made to the simulation between different biological tissue or tissue equivalent.
The radiation dosimetry has a great importance in risk assessment of ionising radiation exposure. From the point of view of risk assessment we characterise several experimental techniques to the determination of the dosimetric quantities (experimental and computational approaches) used in the evaluation of the risk in practical radiation protection problems.

[1] PhD thesis to be presented at the University of Lisbon.
[2] IBILI – Biomedical Institute for Research in Light and Image, University of Coimbra.

Radiobiology

J. H. Pereira Luís, M. L. Pedro and M. J. Figueiredo

Objectives

Research the low-level effect of radiation on chromosomal peripheral blood lymphocytes of individuals professionally exposed to ionising radiation.
Maintenance of operational and standardised biological dosimetry methods, to be used in cases of radiological accident situations or in overexposures to ionising radiation, in order to estimate the dose and the risk to humans.
Development of absorbed dose estimation methodology, based on radiation-induced apoptosis in peripheral blood human lymphocytes, to be applied after a radiological accident or an ionising radiation overexposure.

Results

Uranium Miners
We studied the adaptive response for radiation-induced chromosomal aberrations on low and highly exposed individuals working in Portuguese uranium mines. Adaptive response is defined as an induction of cellular resistance to genotoxic effects caused by subsequently high-dose radiation. Our purpose was to find out if the *in vivo* doses received by miners interfere with the capacity for induction of adaptive responses *in vitro*.
Three working groups were selected on base of total absorbed doses, and on an intensive questionnaire about age, years of work and life styles. One control group was constituted by workers not miners, and the two others groups are miners with average absorbed doses of 10 and 30 cGy respectively. The induction of the cytogenetic adaptive response, on the peripheral blood lymphocytes, was made with a dose of 5 cGy of gamma rays on G1 phase cells, and with a challenge dose of 300 cGy, 5 hours after adaptive dose.
Chromosomal aberration analyses on the control and on the miners group less exposed (10 cGy), showed, that an unknown inducible molecular process triggered by low dose (5 cGy) lead to more enhanced repair of DNA damage, or cell protection, against the deleterious effects induced by subsequent high dose (300 cGy). The analyses of chromosomal aberration, on the peripheral blood of the uranium miner's group individuals, that on average have received 30 cGy, do not show adaptive responses. With the caution about the small number of individuals on our sample, it means, that there are some constraints to enhance DNA repair on this group. We can hypothesise that at these high doses the capacity of repair enzymes are exhausted and no more adaptation is possible.

Radiation Accident Simulation
For maintenance of operational and standardised biological dosimetry methods, to be used in cases of radiological accident situations or in overexposures to ionising radiation, in order to estimate the dose and the risk to humans, we simulate an *in vitro* accident with total body irradiation of 400 rad of source of ^{60}Co gamma rays. The results obtained showed that the absorbed dose estimated by biological dosimetries using chromosomal aberration analysis are in a very good agreement with physical doses applied to the lymphocytes cells *in vitro*.

Retrospective biodosimetry
For retrospective dosimetry stable chromosomal aberrations, like translocations, must be used. The technique of fluorescence *in situ* hybridization (FISH), using the labelling of all centromeres and whole chromosome painting is the suitable one for chromosomal translocation analysis. In this study, human blood samples, of 2 radiation workers accidentally exposed, 22 years ago, to a gamma radiation, whole body doses, 15 - 25 rem, were collected and lymphocyte metaphase preparations are made. We did also, lymphocyte metaphase preparations after irradiation *in vitro,* of control human blood samples, with known cobalt gamma doses. The aberrations were been detected by means of FISH with a cocktail of DNA probes specific for whole chromosomes 1, 4 and 12. The analysis of chromosomal aberrations is delayed because we have not yet a video camera for capture simultaneously the images with all flourocromes.

Published work

[1] Pereira Luís, J.H., Biological dosimetry on radiation protection by cytogenetic methods, *Radioprotecção* **1** (6/7) (2000) 57-64.

Further work

Study the dose-effect relationship for induction of chromosomal aberrations with X-rays and neutrons and conclude the work of Retrospective Biodosimetry by using fluorescence *in situ* hybridization analysis.

Cytogenetic Alterations and Adaptive Response Induced by ^{131}I Treatment in Thyroid Cancer Patients

O. Monteiro Gil, J. Rueff[1], M.B. Martins

Objectives

To study the persistence of cytogenetic lesions in patients treated with radioactive iodine (^{131}I) as treatment for thyroid cancer.
To study the induction of the adaptive response in peripheral lymphocytes of thyroid cancer patients treated with ^{131}I.

Results

As a follow up of the previous published work (Monteiro Gil *et al*., 2000), the cytogenetic lesions induced in peripheral lymphocytes of thyroid cancer patients treated with 2590MBq (70mCi) ^{131}I were evaluated two years after exposure. Our results show a persistence of both chromosomal aberrations (CA (%)) and micronuclei in cytochalasin-blocked human lymphocytes (MNCB (%)) in these patients, notwithstanding, with frequencies lower than at one month after exposure. Indeed, one month after treatment our results were 9.7 and 3.5 for MNCB and CA's respectively, and now, two years later, we found frequencies, for MNCB and CA's, of 9.6 and 2.9 respectively.
The evaluation of an adaptive response induced by ^{131}I was performed in peripheral blood lymphocytes of 11 thyroid cancer patients after treatment with ^{131}I, by assessing the induction of MNCB after a genotoxic challenge *in vitro* with MMC. The results obtained after challenging the lymphocytes with MMC showed a marked reduction in the micronuclei frequency one month after treatment, in 7 of the eleven studied patients, However, we also found a disappearance of the adaptive response, and indeed a higher genotoxicity induced by MMC six months after treatment.

Published work

[1] Monteiro Gil, O., Oliveira, N.G., Rodrigues, A.S., Ferreira, T.C., Limbert, E., Léonard, A., Gerber, G., Rueff, J., Cytogenetic alterations and oxidative stress in thyroid cancer patients after iodine-131 therapy, *Mutagenesis* **15** (2000) 69-75.

Further work

We are currently studying the induction of an adaptive response in peripheral blood lymphocytes of thyroid cancer patients after treatment with ^{131}I, by assessing the induction of MNCB after a challenge in vitro to a radiomimetic agent (bleomycin).
Furthermore studies of DNA polymorphisms of selected genes are ongoing on thyroid cancer patients.

[1] Departamento de Genética,Universidade Nova de Lisboa, Faculdade de Ciências

◈Safety of Nuclear Applications and Radioactive Waste Management

Study of the Actinide Polyoxometalate Systems, mainly the Study of the Interaction of the Lacunary form P_2W_{17} with the Actinide Di-Oxo cation Uranyl $UO_2^{2+(*)}$

Isabel Paiva

Objectives

The general objectives of this Postdoctoral program were the development of knowledge concerning the speciation of actinides in the environment, including the learning of different speciation techniques in solution, the application of software programs to calculate stability constant values for ligand- metal complexes and the overall setup of a speciation laboratory. A particular objective was the study of the interaction of the cation UO_2^{2+} with the lacunary polyoxometalate $P_2W_{17}O_{61}^{10-}$ (also P_2W_{17}), an analogue of a pseudo-colloid, mainly, to analyze whether the defect site on this structure, which is believed to bind the trivalent cations stronger than does the plenary $P_2W_{18}O_{62}^{6-}$ (also P_2W_{18}), have a similar stronger binding for the linear dioxo cations [Choppin, G. R.: DOE Research Proposal 1999-2000]. Solvent extraction and spectrophotometric techniques were applied in this research. A final report about the work carried out at FSU has been presented. Data obtained from this research is still being object of quantitative analysis and the values obtained for the stability constants of the complexes between the different actinides and the polyoxometalate P_2W_{17} studied will be object of further publication. A parallel study involving the use and application of Laser Induced Fluorescence for the identification of the hydration number of Europium adducts of phenanthroline was also carried out in the core of a collaboration between FSU and the Science University of Tokyo.

Research Program and Preliminary Results

Of all the radioactive elements present in the environment, the actinides, in special the transuranics, are of most importance due to their toxicity and negative impact in terms of public perception. One of the most important factors to take into account when devising methods for the monitoring of waste repository integrity, the remediation of contaminated sites or the assessment of radiological impacts in the environment, results from the ability to predict the transport behavior of an actinide release over a period of time as long as a millennium. The primary method of actinide transport within a natural aquifer is according to the following reactions: complexation, sorption, and colloid formation. The majority of the colloids that exist in nature are heterogeneous and difficult to reproduce in lab conditions. Among the compounds that can be used to study actinide migration in natural water systems are the large aggregate metal oxides called polyoxometalates or POM.

Table 1

Spectrophotometric Experiments with P_2W_{17}						
Protonation Constants Input for SQUAD (d)	**Metal**					
	U(VI) (a)		**U(VI) (b)**		**Pu(VI) (c) (s.s.)**	
	$NaClO_4$ 0.1M		$NaClO_4$ 1M		$NaClO_4$ 1M	
	pH	**log β_1**	**pH**	**log β_1**	**pH**	**log β_1**
No Protonation	0.70	3.46±0.01	0.70	3.40±0.02	-	-
	1.57	4.15±0.006	1.57	2.37±0.02	1.7	2.63±0.03
	2.63	4.05±0.01	2.63	4.07±0.02	-	-
H, POM 2.0	1.57	4.75±0.006	1.57	2.37±0.02	1.7	3.99±0.02

The distribution coefficients of UO_2^{2+}, Th^{4+}, and Am^{3+} and NpO_2^+ were measured in the presence and absence of the ligand P_2W_{17} by the solvent extraction technique. As an example of a preliminary result, an average value of log β1 was found for complex UO_2^{2-} - P_2W_{17} (5.60 ± 0.02). Data is still being object of quantitative analysis (in collaboration with Dr. Marian Borkowski, FSU/Argonne).

An investigation of the solution behavior of the complex uranyl ion and lacunary P_2W_{17} by UV-VIS Spectrophotometric technique has been developed in collaboration with Dr. Sergey Sinkov (FSU). Data obtained is still being refined by SQUAD (Stability Quotients from Absorbance Data). The calculated stability constants values are dependent on the protonation constants input. Preliminary data for two specific assumptions are shown in Table 1.

(*) Post – Doctoral Research Work at Chemistry Department, Florida State University

Services

1. Concerted action to establish and run a user group for the EC computer system PC-CREAM

R. Trindade, A. Brogueira, M. Reis

Objectives

- To provide a forum for users and potential users of the EC code system PC CREAM
- To promote the wider use of PC CREAM in the EU thus contributing to a more harmonised approach in assessing the radiological impact of effluent discharges and to achive common safety standards
- To identify where further developments of PC CREAM are required to ensure that it remains "state of the art"
- To suggest improvements to the default data with PC CREAM based on recent experimental research.

Results

The PC CREAM user group contract formally finished at the end of August 2000 and a final report was submitted to European Commission.
The first meeting of the user group was held at NRPB in December 1998. It was pointed out areas where it would like improvements to the system. This led a general discussion of possible areas of improvement based on an NRPB paper and suggestions from the meeting participants. The second meeting was held at NRPB in December 1999. Areas in which the PC CREAM system could be improved and areas for novel development were identified. Participants were asked to rank the improvements in terms of their importance and the likelihood that the required improvement can be achieved.

2. Radiological Survey of Lisboa Sewage System

A. Brogueira, M. M. Sequeira, C. Pires, R. Trindade, F.Gomes, M. A. Pereira, V. Silvino, R. Casquinha

Since 1988 a radiological survey of residual waters from Lisboa sewage pumping system is carried out concerning artificial radioactivity. This work is performed at the request of "Câmara Municipal de Lisboa", through the "Divisão de Controlo de Qualidade" (CML), from the "Departamento de Saneamento", from the "Direcção Municipal de Infra-estruturas e Saneamento". When collecting samples (CML) a radiological control is always carried out (DPRSN). Residual water samples are analysed at the DPRSN by qualitative and quantitative gamma-spectrometry, which is carried out in a Ge detector linked to a 8000 channel analyser.
Collaboration was established between "Câmara Municipal de Lisboa" and "Instituto Tecnológico e Nuclear", which was formalized by means of a Protocol signed by a representative of CML and by the President of the ITN.

3. Radioactive Waste Management

R.Trindade, L. Portugal, F.Teixeira, R. Casquinha

Radioactive waste has always been a mater of great concern for DPRSN. Therefore, besides the waste management of small producers DPRSN has participated in EC committees working groups.
In pursuing the work developed on this matter in previous year, radioactive waste from small producers was collected throughout 2000. After collected the waste was treated, conditioned and put in iterim storage.

4. Detection of radioactive material in scrap metal

R. Trindade, A. Brogueira

Radioactive material was detected and collected during a radiological survey of a truck containing scrap metal, at smelting factory.

5. Nuclear Powered Vessels Staying at National Harbours

L. Portugal, R. Trindade, A. Brogueira, C. Faisca, C. Pires, J. Oliveira, R. Casquinha, P. Duarte, M. Tavares

An environment radioactivity survey is carried out every time a nuclear vessel stays at a national harbour. A monitoring programme consisting on a continuous monitoring of aerosol radioactivity and of airborne radioiodine is carried out. Sampling for gamma spectrometry analysis of water, sediment and biological samples was also perforned. Sampling is done before and after the arrival of the vessel.
Reports with results and conclusions are sent to "Ministério da Defesa". In 2000, three nuclear vessels had stayed at national harbours.

6. Metrological Control Service

A.F. Carvalho, J.V. Cardoso, L. Santos

Metrological control of instruments for measurement of ionising radiation is being carried out under a contract with Portuguese lnstitute of Quality and is the enforcement of Portaria 423/98 de 21 de Julho. Metrological control includes calibration and type testing, During 2000 were calibrated 31 dosimeters and performed type testing of 1 dosimetric system of Armed Forces. About 500 TLD dosimeters were irradiated.

7. Sealed Sources Licencing

R. Trindade, L Portugal, A. Rosa

The license and control of sealed radioactive sources is done according to Decree-Law Nº 153/96. Possession, utilization, transport and import of any radioactive sealed source need to be licensed. The licenses must pay a deposit for each source in their possession. This deposit is refunded when the source is sent back to the original producer or for disposal/storage. Besides that, an annual register of emitted permissions has to be maintained. There is no charge fee for the licensing process. About 80 licences of import were issue in 2000.

8. Radiological monitoring of radioactive cargo in transit

R. Trindade, L. Portugal, D. Alves

Permits for ships containing radioactive cargo to call Portuguese ports are given by ITN. A radiological monitoring programme was carried out when ships transporting nuclear or radioactive materials called Portuguese harbours.

9. Smuggling of nuclear and radioactive material

R. Trindade

Colaboration with the Portuguese Police on detection and identification of suspect smuggling of nuclear or radioactive material to Portuguese territory.

10. Radiological Control of "ITN Campus"

– *Discharges of Radioactive liquid effluents*

R. Trindade, A. Brogueira, C. Pires,
A. Costa, F. Barreira Gomes, R. Pombo

A radiological survey is carried out specially on liquids effluents discharged from RPI and research laboratories to ETAR.

– *Radioactive Gaseous Survey*

M.C. Faísca, M. Reis, C. Pires, M.A. Tavares

A Monitoring programme is carried out with periodically radioactive determinations in aerosol, grass, and rain water samples, in order to control the activity of gaseous releases due to the operation of RPI.

– *Transport of 60Co sealed sources*

R. Trindade, L. Portugal, R. Casquinha

A radiological control was carried out when two ^{60}Co sealed sources, about 100 Ci each, were transported from The Chemistry Group to UTR at ITN.

– *"Piso Técnico" - 1st Floor of the Chemistry Building*

R. Trindade, F. Barreira Gomes

A radiological monitoring was performed during the "cleaning" process of ventilation system of the "Piso Tecnico" located at Departamento Quimica.

– *RPI*

R. Trindade, L. Portugal, F. Gomes, R. Casquinha

A radiological monitoring programme is carried out when RPI is in operation.

11. Radiological Survey of Residual Waters of IPO

A. Brogueira, M.M. Sequeira, C. Pires, M. A. Pereira, V. Silvino

A radiological survey of residual waters from Instituto Português de Oncologia (IPO) is carried out since 1996 concerning artificial radioactivity.
Monthly sampling of residual waters is done by IPO in several retention reservoirs before the IPO outlet and analyses by qualitative and quantitative gamma-spectrometry are done at the DPRSN. Gamma-spectrometry is carried out in a Ge detector linked to a 8000 channel analyser.
This radiological survey is performed at the request of the Instituto Português de Oncologia.

12. Radioactivity in Drinking Waters

G.Ferrador, M.C. Faisca, M.A. Tavares

Following the Portuguese Law (Dec. Lei Nº 236/98), the evaluation of the radioactivity levels in public waters (human consumption) should be performed.
Some water suppliers as "Empresa Pública de Águas de Lisboa- EPAL", "Serviços Municipalizados de abastecimento de Água do Porto – SMASP" , "Águas do Cávado, S.A." and "Águas do Douro e Paiva, S.A. requested regularly measurements of global alpha and beta activities.
A total of 130 global alpha and beta measurements were performed during 2000.

13. Natural Radioactivity in Mineral Waters

G.Ferrador, M.C. Faisca, M.A.Tavares

In order to obtain license concerning the commercialisation of mineral waters, an evaluation of the radioactive levels, consisting in determination of ^{226}Ra concentration and global beta activity should be performed (Dec. Lei Nº 84/90).

Several enterprises of the sector or the national authority concerning the commercialisation of such waters request this radioactive study.
During 2000, a total of 35 radiochemical analysis of ^{226}Ra and global beta measurements were carried out.

14. Natural Radioactivity and Radon Exhalation from Building Materials

M. C. Faisca, P.F. Duarte, C. Pires

Under request or collaboration with private enterprises or users, some building materials were analysed in order to evaluate their natural radioactivity.

15. Indoor Radon

M. C. Faisca, P.F. Duarte

Under request indoor radon measurements were performed in buildings.
Participation in the 2000 Intercomparison of Passive Radon Detectors coordinated by the National Radiological Protection Board (NRPB) U.K.

16. Natural Radioactivity in a Spas Water

M.C. Faisca, G.Ferrador, J.M. Oliveira, P.F. Duarte, C. Pires

Requested by Termas Sulfurosas de Alcafache, S.A., an evaluation of the natural radioactivity concerning monthy samplings in three different springs has been performed. Analyses of global alpha and beta activities, ^{226}Ra, radon , uranium, thorium and polonium have been carried out.
Analyses of global alpha and beta activities and ^{226}Ra were performed at Termas do Crato spas waters requested by the Municipality Authorities.

17. Artificial Radioactivity Levels in Foodstuffs and Other Samples

M.C. Faisca, C. Pires, M.A.Tavares

Under request of the Direcção Geral de Fiscalização e Controlo da Qualidade Alimentar, public or private organisations, different kind of samples, mainly food samples imported or to be exported are monitored (gamma spectrometry analysis) in order to determine concentrations of artificial radionuclides. During this year 30 samples were analysed.

18. Radiation Dosimetry

– *Film Dosimetry*

M. Berta, G. Rangel, A. Gameiro, J. Paiva, M.T. Luzio, A. Rosa

During 2000 about 2,800 workers from 290 facilities professionally exposed to ionizing radiations were controlled meaning approximately 11,100 assessed doses (chart-1). The personal monitor used was the Kodak type II film, changed on a quarterly basis, for the measurement of X ray and gamma radiation.

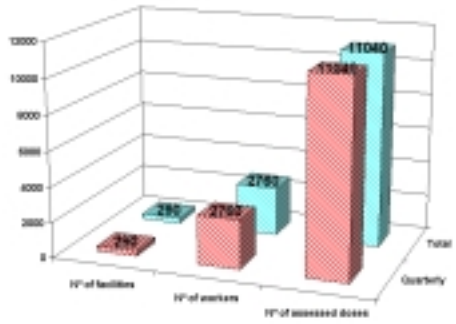

Chart – 1

The number of monitored workers grouped by different fields of activity, namely, health, industry and research laboratories are shown in chart-2.

Chart – 2

The distribution of the annual effective doses by dose intervals is presented in chart-3. It can be seen that the annual doses are distributed in two intervals D<0.5 mSv (~94%) and 0.5≤D<5 mSv (~5%). Annual doses exceeding 50 mSv were not registered and the percentage of workers that received occupational doses higher than 15 mSv is less than 0.1% of the total number of controlled workers (chart-3).

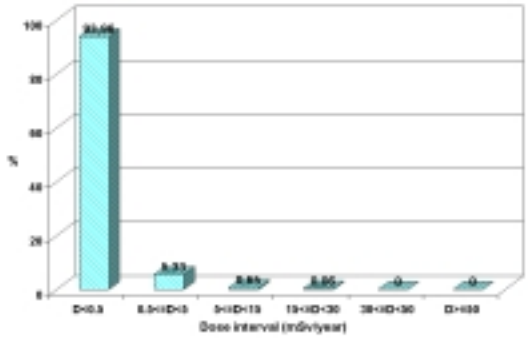

Chart – 3

– ***Thermoluminescence Dosimetry***

J. Alves, E. Amaral, A, Libânio, J. Monteiro, V. Batel, P. Baptista, D. Miranda, S. Rosa, S. Rangel

The evaluation of the occupational radiation doses using thermoluminescence dosimetry is based on the Harshaw 8814 dosemeter card and holder which contains LiF:Mg,Ti detectors. The system allows the measurement of the operational quantities Hp(10) and Hp(0.07), the personal dose equivalents at the depth of 10 and 0.07 mm, respectively.
In 2000, 5800 workers from 570 facilities (aprox.) were controlled with this method on a monthly or a quarterly basis, meaning approximately 41,125 assessed doses (chart 4).

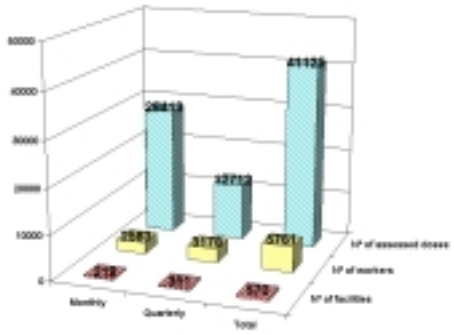

Chart – 4

The number of monitored workers distributed by fields of activity, namely, health, industry, research laboratories and mining are presented in chart-5.

Chart – 5

The distribution of the annual effective doses by dose intervals is presented in chart-6. It can be seen that the annual effective doses are also distributed by the two intervals D < 0.5 mSv (~73%) and 0.5 ≤ D <5 mSv (~24%). Annual doses exceeding 50 mSv were not registered.

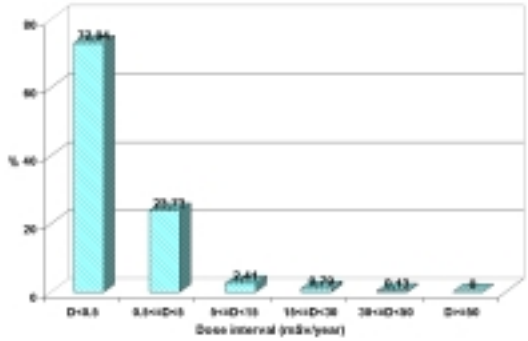

Chart - 6

19. Radiological Safety Assessment

A.D. Oliveira, J.S. Jesus, C.J. Marcelino, K. Jacob, M.E. Pacheco

As a technical service this activity has been necessary for licensing of installations and equipment by the General Directorate for Health of Ministry of Health. According to Decree-Law Nº 348 and Regulamentar-Decree Nº 9/99 the General Directorate for the Health requires DPRSN's radiological safety assessment to give permission for legally allow the operation of any installation or equipment using or producing ionising radiation.
Therefore, radiological safety assessments of installations or equipment during planning, implementation and operational phases, as well as the radiological inspections of the more complex installations and equipment are DPRSN's activities essentially request by the General Directorate of Health. Radiological inspection can also be request directly by the owners of equipment and installations.
In what concerns the radiological safety assessment activity during 2000, 319 studies were request to DPRSN (more 19 comparing with the previous year). These studies involved equipment and installations with different characteristics, both for medical and industrial purposes.
An important task in the year 2000 was the development of a database allowing the management of relevant information of the service. In the next year we initiate the use of the database.
Another important aspect is the modernisation of the methods used in shielding design. We updated some software but more has to be purchased or developed.
To avoid loss of know-how, the formation of trainees is extremely important, including the perspective of their future inclusion in the staff of the Department. Risk assessment is fundamental in radiological safety assessment and radiation protection in general. The trainees in formation are challenged to make an approach to this issue, from the point of view of research in radiation protection, allowing higher level of the services provided.

20. Occupational Medicine

– ***Curative Medicine***

– ***Clinic Pathology Laboratory***

J.E. Ribeiro e Costa, M.F. Fragoso, H. Santos

The medical services develop four different kinds of activities:

- Occupational medicine, in particular concerning radiation protection, including medical inspections for workers exposed to ionising radiation;
- Clinical medicine, as a complimentary service to ITN workers;
- Laboratorial medicine as support to the occupational medicine and clinical medicine;
- Education in medicine and biological aspects of radiation protection and medical advise in case of over-exposure.

The number of medical examinations and clinical analyses done in 2000 are presented in the following table:

Clinical analyses **Total number of analysed parameters**	**1585**	
	ITN & External	**TOTAL**
2. Total medical examinations	1090	**1127**
2.1. Pré-placement health examinations	28	28
2.2. Periodical health examinations	137	37 174
2.3. Work cessation health examinations		15 15
2.4 Occasional health examinations	910	910
3. Worker position reclassifications	4	4
4. Visits to work places	9	9
5. Occupational injuries registered in the individual process	5	5