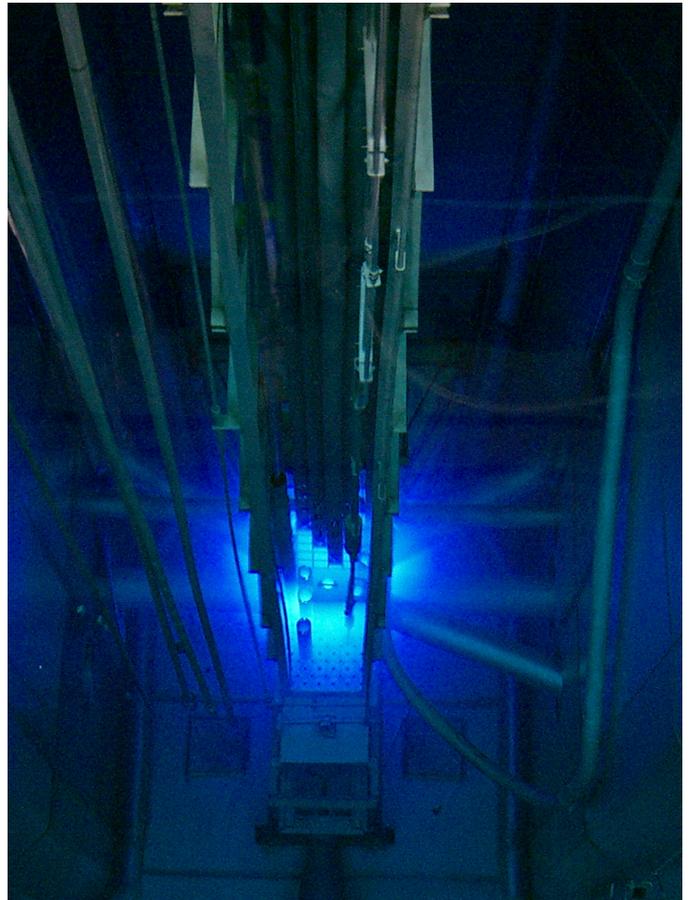


Reactors and Nuclear Safety Unit



Reactors and Nuclear Safety Unit

José Gonçalves Marques

The Research Unit on Reactors and Nuclear Safety includes the *Portuguese Research Reactor* (RPI), a unique infrastructure in the Iberian Peninsula, as well as the *Neutron Activation in Environment, Nutrition and Epidemiology* and *Applied Dynamics* groups. The RPI also supports activities for groups in the other Research Units of ITN, as well as in some Universities. Two new researchers were hired under the *Ciência* initiative during 2009, resulting in a total of 6 researchers hired in 2008 and 2009 in this research unit. This will have a significant impact in the near future, as the number of full-time researchers nearly doubled.

The staff involved in all aspects of the operation and use of the RPI presents its activities under the common headline of *Operation and Exploitation of the Reactor*. A strong effort was made in 2009 for the preparation of the replacement of the instrumentation and control of the RPI. Significant steps were also taken to complete the modernization of the radiological monitoring system. Both efforts will only become visible in 2010.

The *Neutron Activation in Environment, Nutrition and Epidemiology* group uses the k_0 INAA technique in the RPI and was again the main Portuguese user of the reactor in 2009, accounting for nearly 50% of the total irradiation time. The group is dedicated to cycling and impact of trace elements in the

atmosphere. It addresses, specifically, the development and application of nuclear techniques, source apportionment and tracking in the atmosphere, chemical speciation, uptake and release of chemical elements in biomonitoring and monitoring, as well as health linkage through epidemiology and nutrition studies. These objectives are approached through research, included mostly in PhD theses. The activities are essentially financed by the Foundation for Science and Technology (FCT).

The research performed by the *Applied Dynamics* group is mostly concerned by vibration and acoustic problems displayed by components of nuclear and conventional power plants. As such, a significant part of their research results has been motivated and funded by the French *Commissariat à l'Energie Atomique (CEA)* and the Portuguese *Electricidade de Portugal (EDP)*. However, the techniques developed by this group can and have been used to solve problems, both of industrial and fundamental nature, outside the realm of power generation. In spite of continuing to be one of the smallest groups in terms of ITN staff, this fact is compensated by an active collaboration with Universities and Research Laboratories, both in Portugal and abroad. The vitality of this group is well demonstrated by their research contracts and publications.

Staff

Researchers

J. G. MARQUES, Princ.
M. C. FREITAS, Princ.
A. V. ANTUNES, Princ.
A. FALCÃO, Princ.
N. P. BARRADAS, Princ. (85%)
A. KLING, Princ. (85%)
A. R. RAMOS, Aux.
S. M. ALMEIDA, Aux.
D. BEASLEY, Aux. (Contract, since Sept.)
V. DEBUT, Aux. (Contract)
H. M. DUNG, Aux.
A. C. FERNANDES, Aux.
M. A. S. PEREIRA, Aux.

Technical Personnel

J.P. SANTOS, Dosimetry
J. A. M. RIBEIRO, Reactor Operator
J. C. ROXO, Reactor Operator
R. SANTOS, Reactor Operator
N. SERROTE, Reactor Operator
F. B. GOMES, Radioprotection
R. POMBO, Radioprotection
A. RODRIGUES, Technician
I. DIONÍSIO, Laboratory Assistant

Administrative Personnel

T. FERNANDES, Secretariat

OPERATION AND EXPLOITATION OF THE REACTOR

José Gonçalves Marques

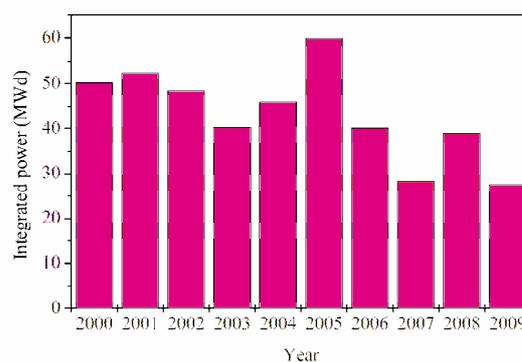
The main objective of the Operation and Exploitation of the Portuguese Research Reactor (RPI) is to be able to satisfy the users' needs while conducting all tasks with the assurance that the reactor is operated in a safe and reliable manner by a highly competent and motivated staff. The implementation of such objectives demands a variety of activities, some of which are repetitive in objective and variable in content, while others address specific aspects of the same end situation.

The main users of the reactor are described in the Table below.

User	Area	Time (%)
URSN	NAA	46.3
	Dosimetry and detector development	7.5
	Radiation effects	2.4
	Education and training	5.0
	Other	1.2
UCQR	NAA	21.3
	Isotope Production	1.9
Univ. Lisboa	Isotope Production	10.7
IVIA	Radiation Effects	3.0
LIP/Lisboa	Isotope Production	0.6
Univ. Coimbra	Isotope Production	0.1

The largest sustained activity supported by the RPI is neutron activation analysis (NAA) in the URSN and UCQR Research Units of ITN. Most other activities

suffer large fluctuations – e.g., education and training is very dependent on the number of students that attend courses that use the reactor in practical sessions. The integrated power in 2009 decreased when compared with 2008, as shown in the figure below, even if in absolute terms the use for NAA increased slightly.



The recent hiring of two researchers for the Operation team, under the *Ciência 2008* initiative, allowed to start an internal program to implement or optimize new techniques, such as neutron tomography and prompt gamma neutron activation analysis, as well as assess the status of experimental setups that had reduced use in the last years and that have the potential to attract new users in a sustained way.

Research Team

Researchers

J.G. MARQUES, Princ.
N.P. BARRADAS, Princ.(85%)
D. BEASLEY, Aux.
A.C. FERNANDES, Aux.
A. KLING, Princ.(85%)
M. A. S. PEREIRA, Aux.
A. R. RAMOS, Aux.

Reactor Operators

J.A.M. RIBEIRO

J.C. ROXO
R. SANTOS
N. SERROTE

Technical Personnel

F.B. GOMES
R. POMBO
A. RODRIGUES
J.P. SANTOS

Students

M.A.F. COSTA, PhD Student, UNL,
FCT grant
A. RICO, MSc. Student, FCT, ITN grant

Collaborators

T. GIRARD, CFNUL
T. MORLAT, Post-doc., CFNUL

Neutron Tomography at the RPI

M.A.S. Pereira, A. Rico, J.G. Marques

Objectives

The objective of this work is to have a neutron tomography setup with an image size of 30 by 30 cm for research and industrial applications at the Portuguese Research Reactor. Significant improvements were made during 2009 to the prototype developed under project “Neutron Tomography at the Portuguese Research Reactor” (POCI/FIS/59287/2004) funded by FCT.

Results

Neutron radiography is a well known non-destructive technique. Compared with X-rays, neutrons have as specific advantages a high interaction probability with hydrogen and a lower attenuation in several heavy elements which are “black” for X-rays. Tomography requires a reasonably high number of 2D images in digital form of the observed object rotated over 180 degrees related to its central axis. With modern CCD cameras it is possible to obtain 2D images in a few minutes, even for modest neutron fluxes of 10^5 n/cm²/s.

A prototype setup for neutron tomography was implemented in the RPI under project POCI/FIS/59287/2004, funded by FCT. The prototype uses a ZnS:Ag scintillator screen, a FingerLakes CCD camera with fast readout, a Nikon 50 mm/f1.4 lens, and a rotary table where the object is placed in front of the beam. The CCD camera is cooled down to -20 C by Peltier effect. Full control of the setup is done

through a custom-made MATLAB application. Images are processed and displayed using the software packages VGStudioMax 2 (Volume Graphics GmbH, Germany) and Octopus (University of Ghent, Belgium).

The prototype was installed in the horizontal access of the thermal column and is thus limited to a parallel beam with 5 cm diameter. During 2009 the neutron and gamma shielding to the CCD camera and the lens were improved, allowing much longer exposures without significant damage to the optics and electronics. Several improvements were made to the MATLAB software application, in order to follow the cooling cycles. The spatial resolution was measured with a standard procedure using Ga foils to be 0.35 mm; it can be further improved using a divergent beam.

Figure 1 shows projections, obtained from a full 3D reconstruction, of a common BIC lighter, with an opaque plastic frame, obtained with the current setup. The level of fluid inside the lighter is clearly visible, as are the plastic pieces under the metallic components on top of the lighter. This setup will soon be used to image historical tiles within project RADIART (PTDC/HIS-HEC/101756/2008) of the UQCR/ITN.

It is expected that the current setup will be transferred to a neutron beam line, using a divergent beam, which will increase the imaging area up to 30 cm by 30 cm, in order to be able to image larger objects.

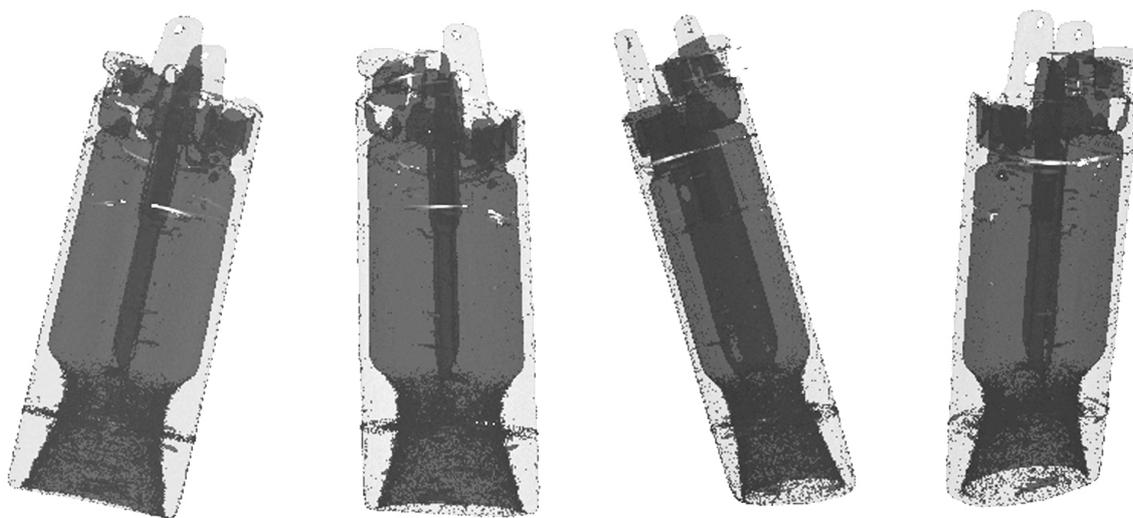
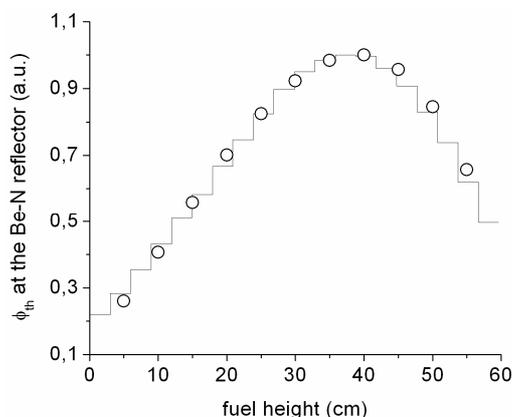


Fig.1 Selected 2D projections taken from a 3D image of a BIC plastic lighter obtained using the neutron tomography setup of the RPI.

MCNP Calculation of Neutron Fluence Rates at the RPI Core

A.C. Fernandes, J.P. Santos, J.G. Marques, A. Kling, A. R. Ramos, N. P. Barradas

Measured thermal (ϕ_{th}), epithermal and fast (ϕ_f) neutron fluence rates and vertical fluence profiles at various positions of the RPI core grid at low burnup conditions were compared with the results of a core model developed with the MCNP5 Monte Carlo code in the criticality mode. The discrepancy between measured and

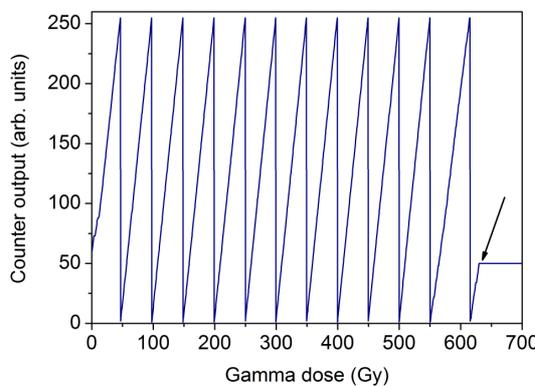


calculated detector responses at 15 cm below core mid-height (where the maximum fluence rate occurs) was generally smaller than 15%. Concerning neutron fluence rates, an agreement better than 85% was also achieved for ϕ_f and ϕ_{th} . The latter case required to apply proper corrections to measurements in the fuel assemblies that include the temperature of the Maxwellian distribution, estimated with the assistance of the MCNP model. In contrast with previous MCNP models for the HEU core, where assemblies at high burnup were used, the present model has allowed to calculate correctly the absolute value of the neutron fluence rates (discarding the need to normalize the calculations to measurements at some points) and the vertical profiles along the whole fuel height (strong discrepancies were observed before, due to a vertically varying burnup).

Radiation Tolerance of Wireless Devices

J.G. Marques, S. Gaillot¹

The performance of electronic components and systems under irradiation is a concern for the nuclear industry, the space community and the high-energy physics community. Wireless industrial process sensors became recently available in the market. Their use in nuclear installations is very attractive, as cabling is nearly reduced to zero, provided they can operate without significant degradation in radiation environments. Several wireless pt100 sensors manufactured by Omega (www.omega.co.uk) were irradiated in the fast neutron facility of the RPI and in the ⁶⁰Co UTR facility, within the scope of the European Integrated Infrastructure Initiative MTR-I3, coordinated by CEA/Cadarache. The target fast neutron fluence and gamma dose defined by CEA were 1×10^{10} n/cm² and 15 kGy. The wireless pt100 sensors survived fast neutron fluences up to 4×10^{12} n/cm², without measurable degradation. On the other hand severe degradation was observed under gamma irradiation for doses above 200 Gy, followed by destruction of the devices above 600 Gy. The performance under radiation of the Omega wireless sensors as available in the market is thus not good enough. Post-mortem examinations of the damaged devices suggest a re-engineering of the power supplies will be necessary for a better performance.



¹CEA, Cadarache, France.

Improvement of Automatic Data Processing for the Radiological Protection of the RPI

A. Kling, D. Beasley, J.G. Marques

For a safe operation of the RPI a thorough and a state-of-the-art radiological control is required. During the year 2009 the main focus in this area lay on the improvement of the automatic processing which is necessary to manage the steadily increasing number of radiological data. A main issue was to eliminate the manual sorting of radiological data according to reactor power levels required for their detailed analysis for reporting. For this purpose existing analysis software has been modified in order to associate the values from a recently installed computerized recording of reactor power level with the data from all automatic radiological control recording systems. Further, an automatic conversion and processing software for the radiological data from measurements with portable instruments (documented daily by the radiation protection technicians in a standardized electronic form) has been developed which can provide processed data for any desired time span.

The SIMPLE Dark Matter Search Project

M. Felizardo, TA Girard¹, T. Morlat¹, A.C. Fernandes, F. Giuliani¹, A.R. Ramos, J.G. Marques, M. Auguste², D. Boyer², A. Cavaillou², C. Sudre², J. Poupeney², H.S. Miley³, R.F. Payne³

The majority of project activity in 2009 centered on the final preparations for a 30 kgd measurement in the underground site, “Laboratoire Souterrain Bas Bruit” (France), including the installation of a 50-75cm thick water shield surrounding the detector water bath (comprising 8 ton in total), and the complete 16 channels of signal and pressure DAQ. Various improvements to the overall system were also made, including:

- Replacement of its freon injection system;
- Installation of two radon monitors; this led to the subsequent discovery of significantly higher than expected levels in the vicinity of the experiment (400-1000 Bq/m³), which was addressed by removing the sound baffles on the GESA ventilation ducts, and increasing the duct flow to 0.2 m/s;
- Execution of various MCNP simulations of the on-detector field neutron, using radio-assays of the GESA 30 cm thick concrete walls, indicating a background rate of 1-4 evt/kgd with 50 cm water shielding.

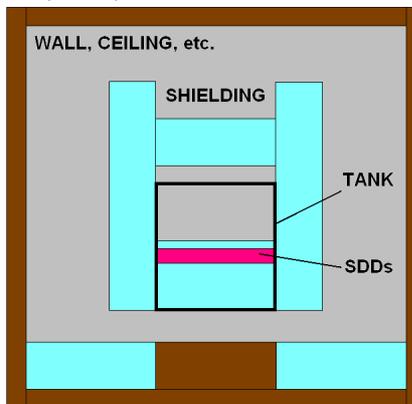
The 16 SDDs were freon-injected and installed from 25 October to 15 November. The measurement has been running since, and already surpassed the 3 kgd measurement goal of PTDC/FIS/57834/2004 by nearly a factor 5, (which was not achieved as a result of funding receipt delays and the unilateral project termination by FCT in June 2008). At the time of this report, the run has achieved a 13 kgd exposure with an accumulated event rate of 7.3 evts/kgd, constituting a factor 25 improvement over that of the 14 kgd PICASSO, and a factor ~ 90 improvement relative to the 52 kgd COUPP. The preliminary results indicate the world’s most restrictive exclusion of a SD WIMP-proton coupling to date, and confirm the competitiveness of the superheated liquid approach in the search for SI couplings. A publication of these results is in preparation.

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² Laboratoire Souterrain á Bas Bruit (Universit  de Nice-Sophia Antipolis), 84400 Rustrel, France
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Shielding Calculations for the SIMPLE Experiment

A.C. Fernandes, M. Felizardo, T. A. Girard¹, A.R. Ramos, T. Morlat¹, A. Kling, J.G. Marques

The natural shielding provided by the “Laboratoire Souterrain Bas Bruit” (France) underground facility for the assessment of the background signal of the superheated droplet detectors (SDDs) of SIMPLE was reinforced with a water shell surrounding the detector water bath. The dimensions of the water shielding leading to an acceptable event rate less than 10 evt/kgd were determined using the MCNP5 Monte Carlo code. The radiation source was defined on the basis of measured uranium and thorium contents of the materials used in the walls of the facility. The simplified geometrical model neglected the curvature of the ceiling, the floor structure and the irregular wall thickness. The results have shown that the radiation background can be reduced 3 orders of magnitude, down to ~1 evt/kgd, using 50 cm of water around the SDDs. Initial measurements using the proposed shielding configuration indicate that an event rate of 8 evt/kgd has been obtained.



¹ Centro de Física Nuclear da Universidade de Lisboa, Lisbon.

Preparation for Replacement of the Instrumentation and Control of the RPI

J.G. Marques

The current instrumentation and control system of the RPI was installed in 1972. Its core results from a combination of analog modules of the Multibloc series of Merlin-Gerin (France) with home-made modules. The replacement of obsolete and hard-to-maintain systems was started in the late nineties but the project for complete replacement of the instrumentation and control system could only be started once it was decided that the RPI would be converted to low-enriched fuel and continue operating after 2006. Standard reactor control modules were manufactured by GammaMetrics (USA), which has a long experience in this area with both research and power reactors. Preliminary engineering projects were made at ITN during late 2008 and 2009 for RPI-specific modules such as the safety interlocks using a combination of high reliability CMOS and conventional relay logic. This approach, one step ahead of simply defining the specifications as a customer, allowed both a decrease in the overall costs and a detailed knowledge of the new system.

Applied Dynamics

José Antunes

The activities at Applied Dynamics Laboratory (ADL) are devoted to research in nuclear engineering, with an emphasis on the vibratory and acoustic behaviour of mechanical components. Our group started in 1986, with the following objectives: (1) Develop theoretical methods, computer tools and experimental techniques, to solve structural problems in nuclear power station components; (2) Use this state-of-the-art know-how, in order to solve structural problems arising in Portuguese power plants and other industrial facilities.

The first objective has been pursued through extensive international collaboration with our main scientific partner - the French Commissariat à l'Energie Atomique (CEA) / Département de Mécanique et Technologie (DMT). More than one decade of fruitful collaboration is attested by a significant number of published results. Important problems have been solved, such as nonlinear vibrations in steam-generators, flow-induced vibrations of nuclear fuel and stability problems in rotating machinery. Furthermore, new identification techniques have been developed and applied with success to nonlinear dynamical systems.

The second objective has been pursued by starting in 1990 a series of projects with (and for) the Portuguese power supplier Electricidade de Portugal / Companhia Portuguesa de Produção de Electricidade (EDP/CPPE), stemming from actual structural problems in power plants (Sines, Setúbal): These projects enabled us to model and solve vibratory problems arising in rotating machinery, vibro-acoustical problems in boilers and heat-exchangers, as well as structural identification problems. Several computer codes have been developed in connection with these projects.

In recent years we also developed research projects of more fundamental nature, mainly funded through the Portuguese Science Foundation (FCT) research programmes. These projects have been developed in partnership with several Portuguese institutions (Faculdade de Ciências de Lisboa, Instituto Politécnico do Porto, Instituto Politécnico de Setúbal, Instituto Superior Técnico, Universidade Nova de Lisboa), as well as the Université de Paris, Trinity

College Dublin and Southampton University. This work, developed in the context of fundamental physics – in particular addressing problems in music acoustics, optimization and structural geology – is centred in modelling nonlinear dynamics and flow-structure phenomena. The methods developed transcend the context of these projects and may be adapted to solve several aspects of industrial problems.

The Applied Dynamics team is mainly concerned with the following scientific fields: structural dynamics, flow-induced vibrations, nonlinear dynamics, vibro-acoustics, experimental methods, signal processing, system identification, structural and acoustical optimization. As a spin-off from our research activities, teaching has been actively pursued on structural dynamics and acoustics - ranging from university level courses in Portugal (Coimbra, Lisbon) to several post-graduation short courses abroad (Paris, Dublin, Cargèse). Also, student and post-doc training, as well as several university thesis (MSc and PhD) have been successfully supervised, for both Portuguese and foreign students. An extensive book on fluid-structure dynamics and acoustics, co-authored by two researchers from CEA and ITN/ADL was internationally published during 2006 and another volume on flow-induced vibrations is currently under completion, to be released in 2009.

Among the above-mentioned scientific fields one should stress those features which give this small group a distinct profile from others working in structural dynamics in Portugal. Those features are: (1) a proven expertise and output in flow-excited systems and nonlinear vibrations; (2) a complementary theoretical/experimental approach for every problem.

Most of the research projects pursued at ADL have been based on both industry and academic research contracts. Research activities at ADL were internationally recognized by two prizes from the American Association of Mechanical Engineers (ASME).

A new researcher joined the permanent staff of the Applied Dynamics group in 2008, being involved since in most of our research activities.

Research Team

Researchers

J. ANTUNES, Princ.
V. DEBUT, Assist. (Contract)

Students

O. INÁCIO (20%), PhD, Adj. Prof., IPP Porto

Collaborators

L. HENRIQUE (10%), PhD, Adj. Prof., IPP Porto
M. MOREIRA (20%), PhD, Adj. Prof., IPS Setúbal
M. PAULINO (10%), MSc, Inv. Prof., IPL Lisboa

Modelling and remote identification of dynamical impact/friction interaction forces

J. Antunes, V. Debut, X. Delaune¹, P. Piteau¹, O. Inácio²

Objectives

Many mechanical components of industrial significance are subjected to impact/friction local forces which are extremely nonlinear in nature. For achieving realistic numerical computations of these systems, a good understanding of the interaction phenomena is of great importance. The direct measurement of such forces is often difficult, due to the lack of room for instrumentation or the aggressive environmental conditions (temperature, radiation). The objective of this project is the *development of modal methods for the remote identification of local contact forces*. This work, performed in close collaboration with CEA/Saclay (France), aims a better knowledge of the local contact/friction laws, in order to refine our modelling techniques and physical understanding.

Results

In this project we focus on two specific problems: (a) A vibro-impacting beam, fairly representative of nuclear steam-generator tubes; (b) A bowed string subjected to self-excited motions. These two problems display complementary features of interest. We have theoretically addressed the vibro-impact modelling and identification problems (experiments are being prepared at CEA/Saclay), while making a full theoretical and experimental study of the bowed string at ADL. Using numerically simulated dynamical responses, we developed an identification technique, based on inverse methods, which can cope with the flow turbulence perturbation (Figure 1). Our modal identification approach also enabled the remote

identification of bow/string interface forces, as well as the self-excited motion at the contact location, from the dynamical reactions measured at the string pinned ends (Figure 2). Effectiveness of the identification method has already been confirmed by post-processing numerical simulations. Furthermore, using the test rig and identification software developed at ADL, the first experimental friction force identifications have been already obtained, with very encouraging results. Various aspects of these were published at three international conferences and two international journal papers. Several more have been already abstracted to be presented at conferences in 2010.

Publications

V. Debut, X. Delaune, J. Antunes, “Identification of nonlinear interaction forces acting on continuous systems using remote measurements of the vibratory responses”, *International Journal of Mechanical Science* (in print).

X. Delaune, J. Antunes, V. Debut, P. Piteau, L. Borsoi, “Modal techniques for remote identification of non-linear reactions at gap-supported tubes under turbulent excitation”, *ASME Journal of Pressure Vessel Technology* (in print).

V. Debut, C. Bersac, J. Antunes, “Identification of the dynamical bow/string friction interaction force from vibratory measurements using inverse methods”. *Proceedings of the 16th International Congress on Sound and Vibration (ICSV09)*, 5-9 July 2009, Krakow, Poland.

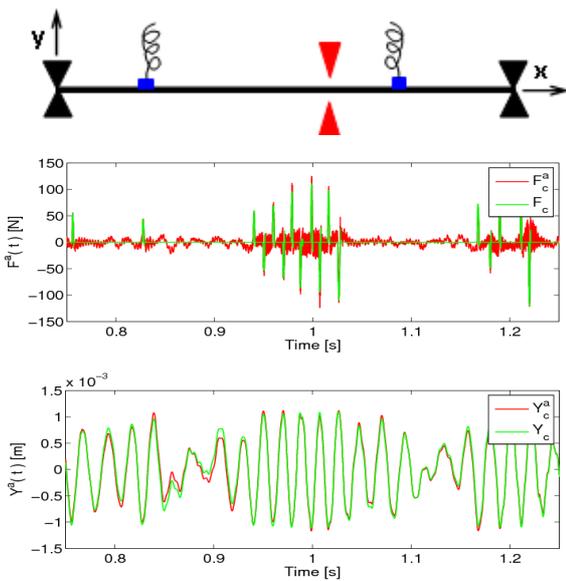


Fig.1 Remote identifications on a vibro-impacting beam: Original (green) and identified (red) impact force and beam motion at the gap-support location.

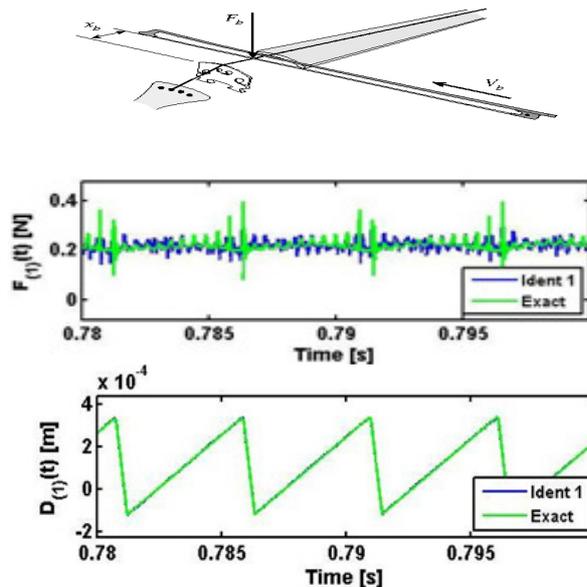


Fig.2 Remote identifications on a bowed string: Original (green) and identified (blue) friction force and string motion at the bow excitation location.

¹ Commissariat à l’Energie Atomique, DEN/DM2S/SEMT/DYN, CEN-Saclay, France

² Instituto Politécnico do Porto, ESMAE, Laboratory of Music Acoustics

Flow-induced vibrations of tubular nuclear components

J. Antunes, P. Piteau¹, X. Delaune¹, L. Borsoi¹

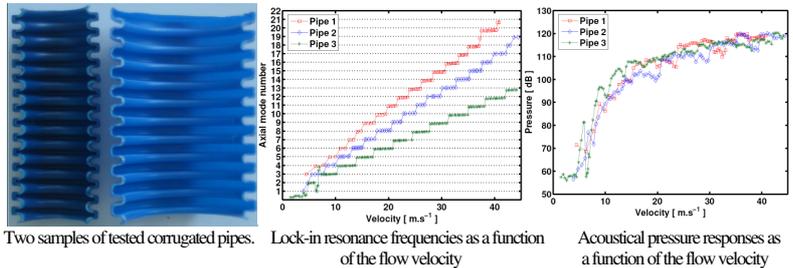
Flow turbulence excitation is a common source of structural vibrations, leading to fatigue failures and wear. For nuclear facilities, such problem must be addressed with particular care, for obvious safety reasons. At ITN/ADL, under contract with CEA-Saclay (contract VITAMINE-3), we gained significant expertise in this area. This project, now in its fourth year, is aimed at the development of up-to-date software to compute the turbulence-induced vibrations of nuclear components such as fuel rods or steam-generator tubes. Nonlinear vibro-impact phenomena between the tubes and their supports are incorporated in the nonlinear time-domain computational models. During 2009, we compared extensively the original method for generating time-domain turbulence excitations, which developed at ADL, with a “direct” method based on the Proper Orthogonal Decomposition (POD) of the cross-spectral complex matrix of the random field. The results obtained are satisfying and of similar quality, however our original technique is computationally more efficient. On the other hand, under a different contract with CEA (contract TGVsurVITAMINE), we developed a computer program for predicting the vibro-impact responses of tubes subjected to the flow fluidelastic forces. The results obtained are currently being validated by experiments performed at CEA-Saclay.

¹ Commissariat à l’Energie Atomique, Lab. of Dynamical Studies, Saclay, France

Modeling and reduction of aeroacoustic noise in flow-conveying systems

V. Debut, J. Antunes, C. Meskell¹, M. Moreira², J. Paulino³

In the context of aerodynamic noise generation, corrugated pipes emit clear and loud lock-in tones, when air flows through them at sufficiently high velocities, due to coupling between vortex shedding triggered by the flow and the acoustical field. Such flow-excited acoustic phenomenon is encountered in a large variety of applications and can induce both environmental noise problems and significant structural vibrations. In recent years we developed a conceptual phenomenological modelling approach to reproduce the qualitative trends observed with experiments in corrugated pipes (Debut & Antunes, 2007), which was explored through extensive numerical time-domain simulations (Debut & Antunes, 2008). During 2009 the effect of small irregularities on the aero-acoustic source characteristics was investigated numerically, showing that dispersion in several of the oscillator parameters can change qualitatively the dynamical behaviour of the nonlinear model. The work on this very difficult problem is still in progress, focusing on aspects connected with the nature of the aeroacoustic sources. To proceed further, a preliminary analysis of the system using Computational Fluid Dynamics (CFD) was started in collaboration with the Department of Mechanical engineering of the Trinity College in Dublin (TCD), which certainly will prove fruitful in the near future.



¹ Trinity College, Dublin, Dept. of Mechanical Engineering

² Inst. Politécnico de Setúbal, Esc. Sup. de Tec., Dept. of Mathematics; ³ Inst. Sup. de Engenharia de Lisboa, Dept. of Mechanical Engineering

Vibro-acoustical modelling of structures coupled with two-phase fluid mixtures

V. Debut, J. Antunes

The nature of energy dissipation mechanisms in bubbly mixtures is an important topic, since many industrial components operating in two-phase flow are prone to flow-induced vibrations (heat exchangers and nuclear steam generators, for instance). To avoid excessive vibrations requires a precise understanding of damping mechanisms. A significant increase of damping is observed in two-phase fluid and, as stated by Pettigrew (1997), “the true nature of energy dissipation mechanisms in two-phase mixtures is still unknown”. The theoretical and experimental project pursued at LDA is intended to bring some light to this problem, by focusing on the specific, and hopefully simpler, case of bubbly stagnant mixtures. Experiments were previously performed on a cylindrical shell filled with a bubbly liquid. This demonstrated qualitatively the strong attenuation due to the “two-phase damping” phenomenon. At the theoretical level, a simple model involving two piston oscillators coupled by a pipe filled with a bubbly liquid was proposed, based on a homogeneous model of bubbly liquid in the form of an extended wave equation (Debut & Antunes, 2008). During 2009, we refined our theoretical formulation using a discrete representation of the bubble population dynamics, coupled with a wave equation for the surrounding liquid. Then, a set of modal ODEs obtained after modal projection provided both numerical time-domain simulations and computation of the coupled modes. Such discrete model highlighted interesting properties of the bubbly liquid damping, in relation with the collective motions of the bubbles or, as an opposed scenario, caused by localized high amplitude bubble breathing. As a result of this work, one international conference paper was published in 2009. Quite recently, a preliminary effort on a more realistic two-dimensional model of the bubbly fluid and shell system was started.

Neutron Activation in Environment, Nutrition and Epidemiology

Maria do Carmo Freitas

The research is focused on development of methodologies in neutron activation analysis and their application to studies of atmospheric environment, nutrition and epidemiology. The investigation appeared as a natural application of the potentialities of k_0 -INAA (instrumental neutron activation analysis using the k_0 -method). The unit activities include the following scientific interests:

Development of Methodologies, Quality Control, Automatization, Data Handling

This line aims to optimize the analytical technique in order to facilitate the analysis of the samples of the different projects, to increase the speed of the calculations and to improve the handling of the data. It also aims to implement methodologies to improve the detection limits for important pollutant chemical elements as cadmium, arsenic, nickel, and to determine lead and the light elements. Steps are being given towards ISO 17025 in order to define protocols and standard procedures. Interlaboratory exercises are targets, aiming analytical quality control.

Monitoring, Biomonitoring

This line aims to characterise areas of Portugal using native vascular plants, mosses and lichens, exposed lichen transplants, air particulate matter collection, and (wet+dry) deposition. The data are analysed for factors aiming at identifying emission sources and the air mass trajectories, including local, regional and long-range transport. To assure the quality of the data, accuracy and precision studies are being performed, both in biomonitoring and monitoring scientific areas. Air particulate matter obtained by different air samplers is compared. So-called conventional analytical techniques are applied to complement the research unit's results. New biomarkers are suggested and studied. Pb-210 is being determined to confirm terrestrial origin of aerosols.

Epidemiological studies

This line includes health related problems. The objective is to link biomonitoring and monitoring to epidemiological studies, at local, regional and world

scale. Children respiratory problems, cardiovascular diseases and carcinogenic incidence in the Portuguese population are being studied in association to chemical elements, pollutant gases and meteorological data. New methodologies are suggested to smooth health and environment data.

Element Uptake Processes

Plant physiology is also one of the group aims, looking for effects on plants due to atmospheric chemical components. The underlying questions are related to the extent in which biomonitors may reflect the element contents of particulate matter. Lichen dynamics, this is, accumulation and release are being deeply studied, as well as lichen titration. Bioremediation at mining abandoned areas is being studied aiming to select strong accumulators of arsenic.

Nutrition

So far, selenium has been the target. It is an essential element to humans and in Portugal its contents in diet is deficient. Therefore, it is aimed to study its supplementation to cereals and to study its absorption (how, how much) in the cereal plant and the cereal grains, via soil and leaves.

Training

The research unit has a strong component in post graduation training (MSc, PhD, post-PhD). A training course was organised by ITN in collaboration with the IAEA, confirming the expertises of the group in aerosol source apportionment. The team is also attending courses to update the knowledge.

Participation in intercomparison exercises

Whenever offered, the group collaborates in intercomparison exercises, to improve its analytical quality.

Services

Analytical services are provided under request. Fluorine with a very short half life is being determined for a German company. Portuguese universities are frequently requesting analyses.

Research Team

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Hyperaccumulation of arsenic and other elements by plants in a mining area: accumulation mechanisms and phytoremediation (PTDC/AMB/65462/2006)

M.C. Freitas, H.M. Anawar, N. Canha, I. Dionísio, A.M.G. Pacheco¹

Objectives

The former mining complex of São Domingos is located at the Lower Alentejo area of southern Portugal, in the heart of the Iberian pyrite belt (northern sector; 37°38'00-37°40'30N, 7°19'05W-7°20'05W), see Fig. 1. The mine has never been properly decommissioned, and its effective abandon has caused a serious impact in local ecosystems, regional watershed and the environment at large. The study aims to determine toxic element levels in superficial soils and waters, and native plants in the mining area, to evaluate the potential of such plants for phytoremediation purposes, especially concerning phytostabilisation of similarly-affected soils.

Results

We collected vascular plants (see Fig. 2) and mine soil in January 2009, performed screening of the plant community and determined toxic elements (As, Hg, Sb), essential (Fe, K, Na, Se, Zn), rare earth (Ce, Hf, La, Rb, Sc), radioactive elements (Th), among others. The concentrations of As, Sb, Fe, and Zn were very high in soil samples (respectively 0.1-0.4%, 0.02-0.1%, 8-19%, and 0.02-0.4%), and stem plant samples (respectively, in mg/kg, 0.4-6.6, 0.1-3.5, 50-500, and 20-500), exceeding the regional background level. This reflects the high magnitude of contamination in and around the mining area: the highest levels were recorded close to tailings pile sites and decreased with distance to it. The results showed that lichen and moss are important biomonitors of terrestrial and atmospheric pollution in mining affected areas [1,2]. We performed different types of experiments to understand hyperaccumulation and detoxification mechanisms of different tolerant plant species. We analysed the plant, lichen, moss and mine soil and tailings samples by both instrumental neutron activation analysis (INAA) and micro-PIXE.

In May 2009, we collected again samples; this time we added lichens and leachate water samples. The latter were analyzed by INAA after freeze drying and reducing the liquid to a powder. The enrichment of the water samples relative to soil are shown in Fig. 3. Two poisoning and carcinogenic elements – As and Cd – were found at high levels in the studied waters, and Cr⁶⁺ is also likely to be present. Speciation of these waters is necessary and intended to be performed in a near future, in order to understand the mechanisms of transfer soil/water. The potential harmful effect of these waters over underground waters must be studied to infer potential health risks for the population resident in the area [3].

Recently, we performed revegetation experiments in the field to assess the phytostabilisation of As and Sb in São Domingos mining soils. This strategy will investigate whether the specific selection of metalloid and metal-tolerant native plant species in conjunction with use of organic compost and mineral amendment can result in a permanent reduction in soil toxicity.



Fig.1 Localization of São Domingos mining area.



Fig.2 Some collected plants (from left to right): *Erica andevalensis*, *Juncus acutus* and *Agrostis castellana*.

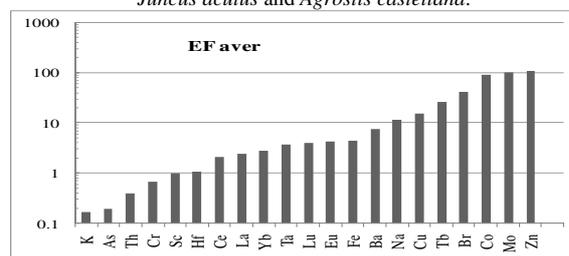


Fig.3 Average of the enrichment factors of the superficial waters at the 6 sites relative to the average soil composition.

Published work

M. C. Freitas, A.M.G. Pacheco, H.M. Anawar, N. Canha, I. Dionísio, A. Bettencourt, F. Henriques, C.J. Pinto-Gomes, S. Capelo. Determination of phytoextraction potential of plant species for toxic elements in soils of abandoned sulphide-mining areas. *J. Radioanal. Nucl. Chem.* 282 (2009) 21–27.

H. M. Anawar, M. C. Freitas, N. Canha. Evaluation of atmospheric dispersion of contaminated mining particulates by biomonitors. Presented to BioMAP-5, Buenos Aires, Argentina, 20-24 September 2009, Paper BM09037, submitted to *Int. J. Environ. Health*.

N. Canha, M.C. Freitas, I. Dionísio, A.M.G. Pacheco, H.M. Anawar. Chemical extraction potential of superficial waters in soils of abandoned sulphide-mining areas. Presented to APSORC-09, Napa, California, 29 November-4 December 2009, Paper # PO-2-11-5, submitted to *Radiochimica Acta*.

¹CERENA/IST.

Use of k_0 -INAA and PIXE in the chemical analysis of filters sampled in an industry with high loadings of metals, PTDC/AMB/65828/2006

S.M. Almeida, T. Pinheiro, M.C. Freitas, P. Félix*, C. Franco*, J. Sousa*, L.C. Alves*, S. Garcia¹*

Workers exposure in a lead processing industry was assessed using Gent Samplers and the combination of the techniques k_0 -INAA and PIXE for chemical analysis. These techniques were advantageously used, and when combined they provided information about 19 elements. The high loadings of elements put some analytical difficulties in the analyses of the filters by k_0 -INAA. The huge amount of Sb in the filters elevated the spectrum baseline, increasing the background, and consequently hindering the identification of weak photopeaks. A Compton suppression system was used in order to reduce the background of the gamma-ray spectrum and, consequently, to lower the detection limits for radionuclides characteristic of the main single gamma-ray emission. Elements which occurred with higher concentrations ($> 10000 \text{ ng/m}^3$) in the workplace were Pb, Sb, Fe, Sn, Na, and Cl. Significant higher element concentrations were measured inside the industry comparing with outdoor environment levels (10000 times higher for Pb and Sb, 1000 times higher for As and Na and 100 times higher for Br, Cl, Fe, and Ni). It was verified that Pb levels exceeded the limit value established by the Portuguese NP1796 for occupational exposure to chemical agents.

* ITN – UFA; ¹ISQ/DS

Impact of atmospheric indoor aerosol in human health, PTDC/SAU-ESA/65597/2006

N. Canha, M.C. Freitas, S.M. Almeida, H.M. Dung, M.A. Trancoso¹

The aim of the project is to investigate the relationship between the indoor air quality of classrooms and the health impact and educational performance of children attending primary schools in Lisbon city. This project has the cooperation of University of Aveiro, INSA-Health National Institute, and LNEG-National Laboratory on Energy and Geology. A set of 14 primary schools in Lisbon area were randomly selected and indoor air quality parameters, such as air particulate matter (APM), bioaerosols (fungi, bacteria and pollens) and natural radioactivity, were sampled or measured through passive methods at two classrooms per school. Until now, three campaigns were done (preliminary, Summer and Autumn) to obtain a seasonal variation of the studied parameters. APM collected passively is analyzed to determine the elemental composition (by k_0 -INAA), soluble ions (by HPLC, atomic absorption and UV spectroscopy) and natural radioactivity (gamma measurement). The figures show the passive collection scheme at the schools.



¹LNEG

Selenium distribution in cereals and Portuguese cultivation soils. Interactions between selenium and iodine uptake by cereals - A case study, PTDC/QUI/65618/2006

C. Galinha¹, A.M.G. Pacheco², M.C. Freitas, H.M. Anawar, H.M. Dung

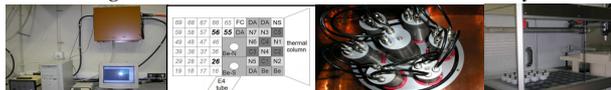
This project is a joint initiative of ITN and IST. This project comprises two stages, each one with different objectives. The objective of the first stage is to determine the regional distribution of selenium in Portugal's most cultivated cereals together with selenium content on cultivation soils, while the second stage's objective is to study the uptake of selenium in different cereals. Samples of various cereals (soft wheat, durum wheat, barley, oat, rye, rice and maize) were collected from the same area of soil samples during harvest time. Selenium in soil and cereal samples are being analyzed by k_0 -INAA on the fast pneumatic system (SIPRA). The short-lived nuclide ^{77m}Se that features a half-life time of 17.5 s is used to determine the selenium content. Soft wheat, durum wheat and barley were seeded with the collaboration of INRB/INIA – Elvas. These crops are used to study the biofortification of selenium, we use different modes of selenium supplementation, foliar addition at different stages of plant growing and the addition to soil together with a fertilizer. Within this project a Waring Blender was acquired to reduce samples to a fine powder, as well as a DSPEC PRO unit to compensate for decaying of short-lived nuclides during short measurements. The figure shows the crops and SIPRA system.



¹DEQ/IST; ²CERENA/IST

Development and application of k_0 -NAA methodologies (across on-going projects)

H.M. Dung, M.C. Freitas, I. Dionisio, D.G. Beasley, S.M. Almeida, N. Canha, C. Galinha, J. Marques



The figures show, from left to right, the SIPRA, RPI's core arrangement showing irradiation positions (Cells 55, 56 and 26-SIPRA), CSS and ASC systems.

The k_0 -based Neutron Activation Analysis (k_0 -NAA) at RPI has been developed and optimized to facilitate the analysis of different sample types for on-going projects, i.e. air filters (Teflon and quartz), plant, bark, lichen, soil, sediment, clay, water, zeolite, fiber,

etc. The chemical elements of interest are Al, As, Br, Ca, Cd, Cl, Co, Cr, Cu, F, Fe, Hf, I, K, La, Mg, Mn, Mo, Na, Ni, Sb, Sc, Se, Sm, Sn, Th, Ti, U, V, W and Zn. The calculation and handling of the data is based on the k_0 -IAEA and SIPRA programs and acquisition software (ORTEC GammaVision V6.0 and CANBERRA Genie-2000). Quality control (QC) and performance evaluations of k_0 -NAA at RPI were performed. The management of the laboratory has followed ISO/IEC-17025 guide-line in order to define protocols and standard operating procedures as well as non-conformances. The achievements were as follows: (1) Characterized the irradiation facilities used for k_0 -NAA after the RPI was converted to LEU fuel. The neutron spectrum parameters were determined at Cell 55: $\Phi_{th}=(8.41\pm 0.09)\times 10^{12}$ n/cm².s, $\alpha=-0.040\pm 0.016$, $f=82\pm 9$ and $T_n(K)=330\pm 16$; at Cell 56: $\Phi_{th}=(2.36\pm 0.15)\times 10^{12}$ n/cm².s, $\alpha=0.040\pm 0.018$, $f=105\pm 11$ and $T_n(K)=318\pm 10$; and at Cell 26 (SIPRA without Cd): $\Phi_{th}=(2.68\pm 0.25)\times 10^{12}$ n/cm².s, $\alpha=0.025\pm 0.015$, $f=113\pm 12$ and $T_n(K)=297\pm 10$; (2) Calibrated periodically all gamma-ray spectroscopy systems, i.e. Compton suppression system (CSS) with and without anti-Compton mode enabled, fast pneumatic transfer system (SIPRA) and automatic sample changers (ASCs); Upgraded SIPRA with a new ORTEC DSPEC-PRO instrument to correct for high dead-times for very short-lived radionuclides; (3) Assessed and improved the quality of k_0 -NAA at RPI, achieving bias for most elements as compared to the certified values at less than 10% and u -scores less than 1.96; Evaluated the reproducibility of the k_0 -NAA with the obtained results and were regarded as stable over 14 months; (4) Documented the protocols and several standard operating procedures as well as non-conformances following the ISO/IEC-17025 guidelines; (5) Developed and applied the k_0 -based Cyclic Neutron Activation Analysis (k_0 -CNAA) on SIPRA for determination of Fluorine (²⁰F, half-life: 11.4 seconds) for fiber material requested by the SemiSol Analytik GmbH, Germany; Analyzed the Zeolite material to optimize the Zeolite production process in a co-operation research with the National Institute for Engineering, Technology and Innovation (INETI).

Characterizing seasonal variations in elemental particulate matter concentrations in European urban and rural areas under different climatic conditions, IAEA RER/2/005

N. Canha, M.C. Freitas, S.M. Almeida, H.M. Dung, I. Dionisio

The aim of this project is to characterize air particulate matter (APM) pollution using nuclear and related analytical techniques in order to identify the pollution sources and to prepare guidelines/recommendations to reduce APM; to assess the impact of APM on human health and the environment. It involves Albany, Bosnia-Herzegovina, Croatia, Greece, Hungary, Montenegro, Poland, Portugal, and Serbia. The participating countries provide staff and resources for the monitoring campaigns and coordinate the activities of all the relevant national stakeholders involved in air quality. IAEA provided training and facilitated the creation of the network through training courses and meetings. The project provides information about concentrations of hazardous particle elements, many of which are regulated today by the World Health Organization and the European Union, and are included in US Environmental Protection Agency list of hazardous air pollutants (HAPS). Our group organized the training course on source apportionment for the project participants, and a meeting was held in Krakow, Poland, to define strategies. The Partisol sequential air sampler was put in Foros de Arrão, Ponte Sor (39°10'39 N; 8°14'25 W) on middle of December 2009. The site is surrounded by homes burning wood for heating and cooking and no other anthropogenic source is known in the area except for small village traffic. The air sampler runs for 3 months, covering the Portuguese colder winter months. IAEA supplied the Teflon filters, and the air sampler contains a meteorological station to register humidity, temperature and pressure. The sampler has autonomy for 2 weeks, therefore every 2 weeks the filters are changed. The urban site is Lisbon where Partisol was running the whole year in 2007; the emission sources relate traffic, industry, soil resuspension, sea spray.

Enhancing the sustainability of Research Reactors and their safe operation through regional cooperation, networking and coalition. IAEA RER/4/032

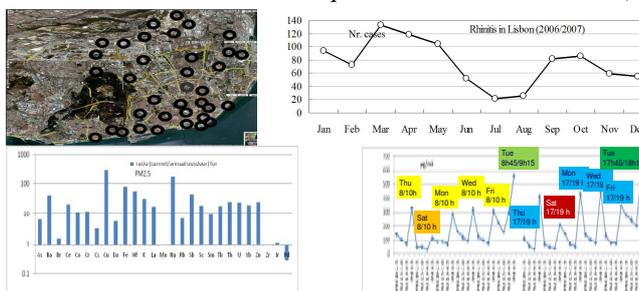
M.C. Freitas, N. Canha, H.M. Dung, S.M. Almeida, D.G. Beasley, J. Marques

At ITN, this project aims at implementing prompt-gamma neutron activation analysis (PGNAA) at the RPI, using an existing facility with an adequate geometry and neutron beam. The work done so far concerns mainly training of the team in order to start the procedures for analytical applications. In that sense, two scientific visits of 2 weeks and week were done at KFKI, Budapest, Hungary, one scientific visit of 1 week at IPEN, Lima, Peru, and, in January/February 2010, two fellowship trainings for 1 month and 2 weeks again at KFKI. The trainings are being fully supported by IAEA. The facility at RPI is not ideal and some adaptations must be done, more similar to the ones of IPEN. The ideal conditions of KFKI will never be reached because it is not possible to extend the neutron beam to larger distance from the reactor and the space where the sample will be irradiated online cannot be reduced. Our difficulty at the moment is the need of reparation of the existing old hyperpure germanium detector or, better, the acquisition of a new one. As soon as the detector is available, the training done so far is enough to start the analytical procedures, aiming the determination of boron and the chemical elements with low atomic number in environmental and nutrition samples.

Association between monthly-reported rhinitis by children from basic schools and monthly-averaged air pollutants, at Lisbon, PTDC/AMB//2004

M.C. Freitas, C. Repolho, I. Dionisio, S.M. Almeida, H.M. Dung, A.M.G. Pacheco¹, C.A. Pio², C.A. Alves², A. Caseiro²

Children are particularly sensitive to the effects of air pollutants, and association with particulates and gaseous pollutants has been demonstrated: in France, increasing levels of outdoor PM₁₀, O₃, and SO₂, were associated with significantly higher rates of asthma and rhinitis in children; in Portugal, an association was found between rhinitis and traffic intensity for 1175 studied children living in Lisbon; hospital admissions in Lisbon due to respiratory conditions were associated with PM₁₀, SO₂, NO₂ and O₃. 1175 children attending basic schools in Lisbon and living in the urban area were invited to respond a questionnaire, for which the answers relevant to this work concerned on positive or negative rhinitis. In case of positive rhinitis, the children reported the month or months with higher frequency of crisis. Their answers were combined with concentrations of outdoor air pollutants in Lisbon. The results showed that traffic related signal was found in three factors, two related to soil resuspension and one to vehicle motors and their associated species (like ozone). The rhinitis component is distributed through the factors. This study suggests different contributors to rhinitis cases, and enhances the role of iridium. Catalytic converters of new cars make use of active compounds, such as the noble metals of the Pt group (mainly Pd, Pt, Rh, and Ir), leading to an increase of such elements in the atmosphere. A study in the Marquês de Pombal tunnel in Lisbon showed clearly the high emissions of Ir and other pollutants during the traffic hours. The figures below show 1) the location of the schools where the questioned students were, 2) the number of children who reported having rhinitis by month, in a total population of 1175 children, 3) the particulate concentrations in the tunnel for PM_{10-2.5}, PM_{2.5-1}, PM_{1-0.5}, and PM_{0.5} for October work days at rush hours and for Saturdays, and 4) the ratio between Lisbon pollutants in air outdoor and air inside the tunnel, for PM_{2.5}.



¹CERENA/IST; ²CESAM/Univ. Aveiro