Nuclear Safety

Radioprotection supervisors care for the radiological safety of workers, public and environment at nuclear and radioactive facilities

Nuclear Safety

Introduction

The Program on Nuclear Safety comprehends Radioprotection, Radioactive Waste Management and Nuclear Material Control. These activities are developed at the Nuclear Safety Directory.

The Radioprotection Service cares for the radiological safety of IPEN workers and general public, through radiation protection programs in accordance with national and international standards. Research related to the main activities is also performed.

The Radioactive Waste Management Department was formally created in 1983, to promote research and development, teaching and service activities in the field of radioactive waste. Its mission is to develop and employ technologies to manage safely the radioactive wastes generated at the Nuclear and Energy Research Institute (IPEN) and at its customer's facilities all over the country, in order to protect the health and the environment of today's and future generations.

The Nuclear Material Control has been performed by the Safeguard Service team, which manages the accountability and the control of nuclear material at IPEN facilities and provides information related to these activities to ABACC and IAEA.

The IPEN Safeguard Service team acts in collaboration with several operators from different Material Balance Areas (MBAs/IPEN). The team makes the annual planning schedule and pre-inventory procedures to accomplish the Physical Inventory Taking (PIT), checks the Design Information Questionnaire (DIQ) and carries out the Physical Inventory Verification (PIV) in order to realize the inspections of the Brazilian National Authority (National Nuclear Energy Commission / CNEN), Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) and International Atomic Energy Agency (IAEA) in compliance with the Quadripartite Safeguards Agreement (INFCIRC 435). This agreement was signed by Argentina, Brazil, ABACC and IAEA, and it adopts the Common System of Accounting for the Control of Nuclear Materials SCCC for Brazil / Argentine. During the period 2008-2010, the Safeguards Service team managed the nuclear material control of the areas under the INFCIRC 435 agreement and carried out records as the General Accountability Book and the Notifications for Movement of Nuclear Material to support the Inventory Variation Report issued by CNEN. The Safeguard Service team has been following the inspections of CNEN, ABACC and IAEA.

Environmental risk assessment

Evaluation of the contamination risk caused by lightning rods disposed at uncontrolled garbage dumps

Americium-241 (^{241}Am) migration experiments were performed in order to evaluate the risk of contamination caused by disposition of radioactive lightning rods as common solid waste. Sources removed from lightning rods were placed inside lysimeters filled with organic waste, and the generated leachate was periodically analyzed to determine its characteristics, such as pH, redox potential, solid content and the concentration of the radioactive material. Besides the risk evaluation, the mechanism of the ^{241}Am release or retention in waste as well as its influence in the waste decomposition processes was investigated. Leachate samples collected in a lysimeter were periodically analyzed for bacterial growth, under both aerobic and anaerobic conditions. Results revealed that ^{241}Am inhibited bacterial growth, and the degradation of organic matter was delayed in comparison with the control. Figure 1 shows the inhibition of bacterial growth by americium.

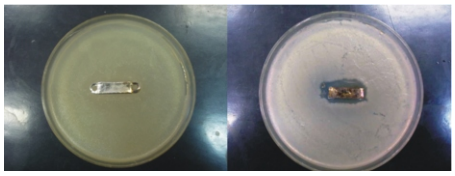

Figure 1. Culture plates showing antimicrobial action of americium: a) steel base without ^{241}Am; b) bacterial growth inhibition halo around the ^{241}Am strip

Public perception of risks associated with radioactive waste

It is well known that one of the major concerns regarding the peaceful use of nuclear energy is related to the safe management of the radioactive wastes. Nuclear energy has always been a polemic issue, and it is usually more intensely associated, by the general public, with the risks than with the benefits from its use. The aim of this study is to try to understand how local public will face to the construction of a nuclear waste repository and what role the mass media plays in the formation of public opinion. The coverage of the nuclear issue in the press, identifying the amount of negative and positive views on the subject, as well as the people involved in the process, were analyzed comprising the period from February 2007 to February 2008. From that sample, 172 texts published in widely known newspapers and magazines, most of them from Sao Paulo State, were identified. The analyzed speeches were classified according to five information sources: specialists, users, authorities, protagonists and entrepreneurs. It was noted the predominance of positive articles, mainly due to the weight of the favorable speeches by authorities, cited as the most frequent in this paper.
Another ongoing study deals with the assessment of the public perception of risks associated with the construction of the national radioactive waste repository, aiming at supporting project managers to establish an effective communication program with the society. A questionnaire to be applied in an opinion pool have been developed, in order to evaluate the following aspects: attitudes toward radioactive waste and nuclear power, risk denial, beliefs, stigmata, social and epistemic trust, antagonism, expressed preferences, technological risk, emotional reactions and the precautionary principle. The questionnaire is being applied for validation and adjustment.

Radioactive waste characterization, treatment and disposal

Characterization of ion exchange resins and activated charcoal

The radioactive waste characterization program of GRR follows the guidelines of "IAEA-TEC-1537 - Strategy and methodology for radioactive waste characterization" in order to complete, for each waste stream and each waste package, the waste form required by CNEN-NN 6.09 - Acceptance criteria for disposal of low - and intermediate- level radioactive wastes. The main development goals are to set up routine radioanalytical methods and the determination of scaling factors and correlation functions that allow calculate the radioactive inventory of difficult to measure radionuclides (DMR) from the activity of key radionuclides (KR), present in the wastes. DMR include alpha and pure beta emitters, and low energy, low yield gamma emitters that require radiochemical treatment of waste samples to be quantified. KR include gamma emitters that can be detected and quantified by simple gamma spectroscopy or calibrated gamma scanning of waste packages, like Cobalt-60 and Caesium-137. This method is being applied for characterization of ion-exchange resins and activated charcoal beds replaced from the water treatment system of the IEA-R1 research reactor. Radioanalytical methods for determination of twenty one fission and activation products as well actinides were developed and/or implemented to measure the radioactivity concentration of forty nine samples taken from twenty one waste drums containing that kind of waste.

Optimization of the radioactive waste storage

IPEN is optimizing the radioactive waste storage capacity, taking into account that a fraction of the stored treated wastes has decayed to a very low level and considering that "retrieval for disposal as very low level radioactive waste" is one of the actions suggested to radioactive waste managers. The optimization study evaluated two main options: either to maintain the present situation or to open old packages and segregate the wastes that may be subject to clearance levels. The results showed that maintaining the present situation is not the best option, even though some parameters of each scenario may be reevaluated. In 2010, a new storage facility was constructed and all treated waste packages were transferred to it. All the

packages that may be subject to clearance levels were stored separately for further segregation.

Isotopic characterization of radioactive waste drum

An automated system for isotopic characterization of radioactive waste by gamma scanning of waste drums was developed (Fig. 2). The detection system is composed of an HPGe detector and associated electronics. The drive system of drum is automated and controlled by a PLC (Programmable Logic Controller). This system allows controlling the elevation and rotation of a base where the radioactive waste drum is positioned. The system operates in continuous and in programmable mode, in which the number of measurements, operation time and the axial positioning of the detector in the drum can be preset. This system associated with the mathematical techniques such as Monte Carlo Method and Artificial Neural Networks are efficient in isotopic characterization of radioactive waste drums.

Figure 2. Automated system for isotopic characterization of radioactive waste drums

Treatment and disposal of disused sealed sources

The R&D work undertaken in respect to the management of lightning rods, smoke detectors and other disused sealed radioactive sources (SRS) is divided into designing the facilities to handle the sources, decontaminate lightning rod scrap metal and into developing the concept of a deep, fully-dedicated repository to dispose of SRS.

During the reported period, the hot cell designed to handle the sealed sources was further assembled, with wiring, pneumatic lines and accessories being partially installed. The methodology of SRS characterization was developed either for simple certification of the data supplied by owner or for identification of the radionuclide and quantification of its activity in the case of orphan sources.

The contribution of the IPEN for the establishment of a feasible alternative for final disposal of SRS continued in the period, with further development the concept of repository in a deep borehole. The assessment of the durability of cementitious material under the conditions deemed to prevail in the deep environment continued by accelerated tests in laboratory. Specimens of Portland cement paste undergone irradiation and high temperature storage and the effects on the paste properties were analyzed by X-ray diffraction, electron microscopy and other techniques (Fig. 3). The results of this work showed that exposure of cement paste specimens to the stressing factors induced changes in cement properties that could affect the performance of this engineered barrier in the long term. Results also showed that some analytical methods were capable of detecting those changes in the cement properties, for instance, mineralogy changes detected by X-ray diffraction and by scanning electron microscopy while others must be improved, e.g. reduction of mechanical strength as measured by axial compression of exposed specimens.

The methods for assessing the safety of such a facility were investigated in two lines of research: one looking for qualitative and quantitative safety indicators, which could be applied to the licensing of a disposal facility, and the other integrating different lines of evidence to build confidence in the acceptability of the disposal concept.

Aspects of site analysis and selection for a disposal facility were approached by searching literature with description of the geological features of a model sites.

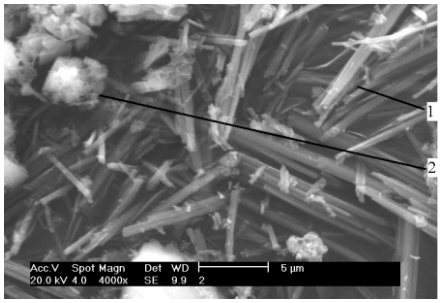

Figure 3. Scanning electron micrograph of precipitates on the cement paste specimen surface showing needles of ettringite (1) and grains of Porlandite (2)

Treatment of radioactive liquid wastes using different biomasses

In order to reduce the volume of radioactive liquid wastes stored at the IPEN, the method based on the capacity of biopolymers to remove heavy metals from wastewater has been developed. Among the biopolymers, alginate beads, agricultural waste (sugar cane bagasse, coconuts fiber and rice husks) and microbial (Saccharomyces cerevisae, Ochrobactrum sp, C. metallidurans and B subtilis) biomasses have been studied to remove Americium-241 from aqueous solution. The following parameters were evaluated: contact time, pH and radionuclide concentration. The removal of plutonium and cesium from radioactive liquid

wastes were also assessed using agricultural wastes as vegetal biomasses. The bioremoval technique has been so far considered efficient (removal >90%), low cost and sustainable. Figure 4 shows the reduction of waste volume obtained with alginate beads.

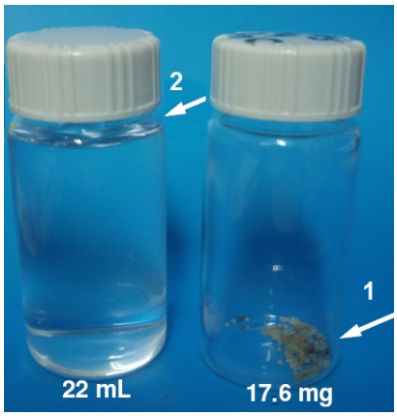

Figure 4. Reduction of the volume using alginate beads: 1- aqueous solution with Americium-241; 2- alginate beads after the biossorption process

Occupational epidemiology

The main evidence for the presence or absence of various health outcomes is provided by epidemiological investigations. The main objectives of the research group are:

- To get a solid introduction and a detailed study of the basic epidemiologic methods including the special features of occupational epidemiology;
- To assess the different types of epidemiological study, the applications, advantages, and limitations of the major types of observational and experimental studies, emphasizing the many possibilities for errors in epidemiological for a clear understanding;
- To use epidemiological principles and methods to the practice application of data derived from epidemiologic research, in particular for the radiation epidemiology;
- To determine the possible health consequences of the workplace exposures (exposure standard setting) and to recommend remedial efforts, when applicable.

Presently, with the emphasis in studies about quality of life (QOL) involving workers with potential risk to ionizing radiation has been carried out, in order to identify the social-demographic factors related to these workers and its influence on QOL, as well to establish the profile of workers handling radioactive material.

Radioactive waste management

The Radioactive Waste Management Department is responsible for reception, treatment and interim storage of the radioactive waste generated at IPEN, as well as those generated at many other radioactive facilities all over the country. IPEN has units for: waste reception and segregation; decontamination of small pieces; liquid waste immobilization and conditioning; in-drum compaction; disassembling of radioactive lightning rods; storage of disused sealed sources; storage of untreated and treated wastes; characterization of primary wastes and waste forms. The existing storage for treated waste is being restructured to receive 850 m^2 of extra area, divided into two sheds. The first shed was concluded in 2010 and treated waste was transferred from the old building to the new one (Fig 5). The second shed will be concluded by July, 2011 to receive untreated wastes. It is noteworthy that in the reported period 113 neutron sources were repatriated to Los Alamos National Laboratory (USA), as part of cooperation program between CNEN and IAEA.

Figure 5. New radioactive waste storage building (outside and inside view)

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Radioprotection Service

The main task of the Radioprotection Service of IPEN is to provide for IPEN workers and for general public an adequate protection against ionizing radiation. The Radioprotection Service implements appropriate procedures and monitoring techniques according to the national and international standards.

The team helps the employer to comply with the requirements specified by the National Regulatory Authority. The Radioprotection Service provides support to general obligations for any practices which involve or could involve exposure to radiation or radioactive substances in compliance with the standards that include:

- Preparation of local rules and procedures;
- Designation of radiological areas;
- Control and accounting of radioactive material;
- Restriction of exposure;
- Optimization of radioprotection for practices;
- Individual dosimetry (internal and external) and dose assessment;
- Ocupational and environmental control and contamination monitoring;
- Contingency planning and radiological risk assessment;
- Training in radiological protection.

In additional, when required, the Radioprotection Service can provide the following services:

- Preparation and review of radiological protection aspects of safety documents;
- Advice and assistance on radiological aspects of categorization of plant and modifications;
- Participation in safety audits;
- Support to engineering projects;
- Analysis of transport packages and waste contents, including assistance with waste characterization;
- Investigation of abnormal dosimetry results;
- Routine reports on personal dose statistics;
- Provision of appropriate radiological information for reports;
- Personal protective equipment including respiratory protection;
- Preparedness and emergency response involving radioactive material.

The Radioprotection Service is available to the customers 24 hours per day. During 2008-2010, the Radioprotection Service in the field of emergency response and preparedness in Brazil has been carried out according to the expected work program.

Concerning the program for the improvement of infrastructures for protection and safety at IPEN, the Radioprotection is the authority responsible for managing the radiological activities survey of access areas under the direction and instructions of Radioprotection staff. The Radioprotection Service is updating in a continuous way its procedures in order to fulfill the new legal requirements derived from the Standards.

Preparedness and response to nuclear and radiological emergencies

IPEN is an operational unit of the Protection System for the Brazilian Nuclear Program (SIPRON) that is a group of organizations with the objectives of the integrated planning, the combined action and the continuous execution of measures in order to assure the nuclear safety in the country and to respond to radiological and nuclear accidents in Brazil. IPEN also takes part in the implementation of the Emergency Situation plan that was developed by the National Commission of Nuclear Energy (CNEN) to respond to nuclear or radiological emergencies, as loss of radioactive sources and accidents during the transport of radioactive material.

The Nuclear and Radiological Emergency Response Team (NRERT) of the Radioprotection Service is responsible for the evaluation and first response to situations of nuclear or radiological emergencies in São Paulo state. NRERT works with other federal and local agencies to monitor, contain, and clean up the release of radioactive material for protecting people and the environment from harmful exposure to radiation.

Training in radiation protection at IPEN

The Radioprotection Service is responsible for the development and implementation of training in radiation protection for a range of users and applications of ionizing radiation. This activity has been established to attend: the training requirements for IPEN workers for any levels; to emergency response personnel, such us fire fighters, civil defense personnel; and to provide and disseminate information in radiation protection education for students and community.

Workers who are occupationally exposed to ionizing radiation need more extensive and deeper training to ensure that radiation is used safely. The training of the principles of radiation protection is based on the Standards of the CNEN and IAEA (International Atomic Energy Agency). The competences are acquired, developed and maintained through a programme of regular training. The courses are offered, such as basic training, refresher training and on the job training. The content and level of the courses offered are established for each category of persons to be trained.

For the 2008-2010 period, the courses were offered periodically. Upon completion of the course, an examination is given to authenticate the program requirements. A Certificate of Achievement is provided to those who have successfully completed the course, and a permanent record of training is kept in the Radioprotection office. The basic course covers the general principles of occupational

radiation protection in the following subject areas: basic radiation physics, definitions and units of radioactivity, principles of radiation protection against external and internal exposures, biological effects of radiation, the risk and assessment of such exposures, instrumentation, inventory and contamination control, emergency response, requirements of the National and International Standards and IPEN procedures. After this basic course all workers must be trained in this specific practice in each work area. The Radioprotection Service provided training to workers as shown in Figure 6.

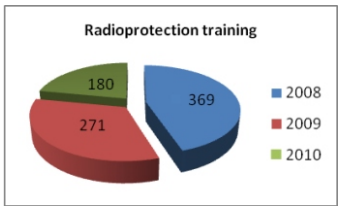

Figure 6. Number the workers trained on protection and safety over the years

In addition, the Radioprotection Service has participated in graduate course to obtain Master Science and Ph.D. Title in the Nuclear Technology-Application Area.

Nuclear Safety

Program Team

Research Staff

Dr. Ademar José Potiens Jr; Dr. Demerval Leônidas Rodrigues; Dr. Goro Hiromoto; Dr. Janete Cristina G. G. Carneiro; Dr. José Cláudio Dellamano; Dr. Júlio Takehiro Marumo; Dr. Kátia Aparecida Fonseca Normanton; Dr. Linda V.E. Caldas; Dr. Malvina Boni Mitake; Dr. Nelson Leon Meldonian; Dr. Reynaldo Serra Cavalcanti; Dr. Roberto Vicente; Dr. Solange Kazumi Sakata; Dr. Teresinha de Moraes da Silva; Dr. Valdir Maciel Lopes; MSc. Eduardo Gerulis; MSc. Fábio Fumio Suzuki; MSc. Matias Puga Sanches; MSc. Sandra Aparecida Bellintani; BSc. Carlos A. R. da Costa; BSc. Christovam Romero Romero Filho; BSc. Eduardo Cardoso Monteiro; BSc. Eduardo Yoshio Toyoda; BSc. Eduardo Wilson M. dos Santos; BSc. Estanislau Borges Vianna; BSc. Evandro Alves Almeida; BSc. Francisco Mário Feijó Vasques; BSc. Hissae Miyamoto; BSc. José Roberto Araújo Nicolau; BSc. Jurandyr S. de Carvalho; BSc. Olavo Pedro da Silva; BSc. Paulo Brasil Sanches Cambises; BSc. Ricardo Nunes de Carvalho; Tech. Antonio Alves de Andrade; Tech. Celso Augusto Jacomini; Tech. Cláudio Calixto de Almeida; Tech. Cláudio Manoel Constancio; Tech. Ethel Martins Pedroso; Tech. Flávio Luiz Rossatto; Tech. Haroldo Ramos da Silva; Tech. Hélcio Luiz Apostólico Jr.; Tech. Hélio Francisco Leôncio; Tech. Ivanatã Martins da Silva; Tech. José Carlos Barbosa da Silva; Tech. José Laércio de Carvalho; Tech. Julio Evangelista de Paiva; Tech. Juscelino Martins de Oliveira; Tech. Manoel D. F. Brandão; Tech. Marcos Maciel de Goes; Tech. Maria Aparerida Gonçalves; Tech. Maria Cristina Santos Ferreira; Tech. Massao Kamonseki; Tech. Paulo Antonio Mestre; Tech. Ricardo Borbon Lemes; Tech. Robson de Jesus Ferreira; Tech. Sidnei de Lima; Tech. Vera Lúcia Keiko Isiki; Tech. Vicente Rodrigues Júnior; Carlos Alberto Ferreira da Silva; Donata Celicea de Oliveira Zanin; Filomena De Fina Beraldo; Ieda Ribeiro Tavares Venâncio.

Graduate Students

Alex Barbosa; Amanda Juliene da Silva; Bianca Geraldo; Cristiane Teixeira Manetti; Eliana Rodrigues de Leite; Felipe Ramos Correa; Ivani M. Fernandes; Kátia Suemi Tanimoto; Leandro Goulart de Araujo; Maurício Guimaraes Sabbag; Paula Perrucho Nou Silva; Rafael Vicente de Pádua Ferreira; Rosana L'agua de Oliveira; Tânia Regina de Borba.

Undergraduate Students

Aline Sayuri Takara; Alvaro Wei Chiang Wang; Ana Carolina Martins; André de Oliveira; Carina Machado do Nascimento; Catia Kim; Daiane Cristini Barbosa de Souza; Daniel Terio Kanashiro; Denise Minematsu; Eduardo Gurzoni Alvares Ferreira; Érico Sant'anna Perrella; Fernando Nogueira da Silva; Guilherme Altomari Geribola; Heverton Cardan Oda Fonseca; Jacqueline dos Santos Rodrigues Silva; Jaime Souza Borges; Josenilson Barbosa de Lima; Juliana Meira Matavelli; Lucyana Martin Falcon Gomes; Ludmila Cabreira Vieira; Luis Henrique Florêncio; Marcos Paulo Pianissola de Cerqueira; Maximiliano Bruno da Silva Guimarães; Mirella Curto Gomes; Nadia Suemi Nobre Ota; Paulo Henrique Senise; Priscila Batalha de Lima; Reginaldo Vitorino dos Santos; Renato Camargo; Rozilene Elaine da Silva; Zenaide Aparecida Figueiredo.

Co-Workers

Dr. Gian-Maria A. A. Sordi; MSc. Adelia Sahyun; MSc. Maria Helena Tirollo Taddei.

Honor Mentions and Awards

Catia Kim, an undergraduate student supervised by Dr. Júlio Takehiro Marumo of Waste Management Department, received an award for the third best junior poster presented at INAC - International Nuclear Conference, held in Rio de Janeiro from September 27 to October 2, 2009. The title of work is "Application of advanced oxidative process in treatment radioactive waste".