RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM FOR PRE-OPERATIONAL BRAZILIAN MULTIPURPOUSE REACTOR (RMB) – GAMMA IN SITU SURVEY RESULTS

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ABSTRACT

The Brazilian Multipurpose Reactor (RMB) is a venture sponsored by the Federal government. The National Commission for Nuclear Energy is responsible for its construction and operation. Its main applications are to produce radioisotopes and radioactive sources for health, industry, agriculture and environment; irradiate materials and nuclear fuels, to allow its analysis of performance and behavior under irradiation in nuclear reactors; scientific and technological research with beams of neutrons. The city of Iperó was chosen as the site for its installation. In this area, the Experimental Center of Aramar (CEA), a venture developed and operated by the Navy Technological Center in Sao Paulo (CTMSP), has been operating since April 1988, as part of its development program nuclear propulsion. The CEA is located at Ipanema Farm, 10 km from the city of Iperó and 15 km from the city of Sorocaba, Brazil. The area subject to gamma in situ survey should cover 5 Km radius around it (area of direct influence of the reactor) and 10 Km radius around it (area of indirect influence). Current data related to the land and water uses are raised by researchers responsible for the description of this item through site visits and sampling campaigns for data collection more consistent with current realities in the region. For a gamma survey of local background, in situ measurements in large areas were performed using sodium iodide detectors, assembled in car. Measurements were made within in a period of one week and the results were satisfactory and consistent with the background and showed similar values when compared with other areas with the same characteristics.
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1. INTRODUCTION

The RMB will be an open pool multipurpose research reactor, using low enriched uranium fuel, with a neutron flux higher than $2x10^{14}$ $n/cm^2.s$. Its power will still be set within the range of 20 to 50 MW. The estimated cost is around USD 500,000,000 and its operation is scheduled to start in 2016. The RMB project implementation is of responsibility of the National Nuclear Energy Commission (CNEN), which through its Directorate of Research and Development (DPD) coordinates the development work carried out by its research institutes, namely Nuclear and Energy Research Institute (IPEN), Nuclear Engineering Institute (IEN), Development Center of Nuclear Technology (CDTN) and Regional Center for Nuclear Sciences (Northeast CRCN-NE), Institute of Radiation Protection and Dosimetry (IRD), and Poços de Caldas Laboratory (LAPOC). The development of the project also includes the partnership of the Navy Technological Center in Sao Paulo (CTMSP) and other research centers and universities across the country, generating synergy between the national scientific and technical areas.

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The RMB has established a target of the Plan of Action on Science and Technology Innovation of the MCT in 2007, aligned with the strategic policies of the government for the Brazilian Nuclear Program, and in order to provide the country with a nuclear research reactor for the following applications: radioisotope production (mainly molybdenum); fuel and material irradiation testing to support the Brazilian nuclear energy program; and provide neutron beams for scientific and applied research. Its site has already been selected, and the conceptual design is under development.

1.1. Licensing Process

For projects or activities considered to be potentially or effectively polluting, the development of the Study of Environmental Impact (EIA), to be completed by its respective report (RIMA) is required. This study is part of the licensing process and the concession of referred license depends on its approval. Licensing process of some specific activities, as the RMB, will have to be analyzed by the federal environmental body (IBAMA – Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis).
To install and develop such projects, the entrepreneur shall obtain the following licenses:

- Previous License - LP, containing prescriptions to be followed during localization, installation and operational phases, according to federal, state and municipal standards;
- Installation License - LI, authorization of beginning of implantation, according to the previous license and;
- Operational License - LO, authorizing, after due inspections, beginning of activities and its pollution control equipment, according to previous and installation licenses.

The licensing regulation CNEN-NE-1.04 establishes that no facility shall operate without a nuclear license. It also establishes the necessary review and assessment process, including the specification of the documentation to be presented to CNEN at each phase of the licensing process. It finally establishes a system of regulatory inspections and the corresponding enforcement mechanisms to ensure that the licensing conditions are being fulfilled. The enforcement mechanisms include the authority of CNEN to modify, suspend or remove the license. The licensing process is divided in several steps: Site Approval; Construction License; Authorization for Nuclear Material Utilization; Authorization for Initial Operation; Authorization for Permanent Operation; Authorization for Decommissioning [1].

Both licensing process, environmental and nuclear, require the elaboration and the implementation of a Pre-Operational Radiological Monitoring Program (Preoperational PMRA). The entrepreneur should conduct this Program at least two years prior to initial criticality of the reactor. The pre-operational program documents the background levels of direct radiation and concentrations of radionuclides that exist in the environment. It also provides an opportunity for the licensee to train personnel, and to evaluate procedures, equipment, and techniques.

In order to attain these objectives, a Preoperational PMRA was elaborated for the RMB, which includes the collection and analysis of radionuclides concentration of different environmental samples (soil, air, sediment, surface and ground water, biota, among others), as well as the measurement of the background levels of direct radiation. This paper presents the results of a gamma in situ survey carried out at site were the RMB will be constructed. The results allowed evaluating the background levels due to direct gamma exposure.

1.2. Area of Study

The Aramar Nuclear Experimental Center (CEA), in Iperó, state of São Paulo, has been selected to be the RMB site. The CEA is located at Ipanema Farm, Iperó-SP, 15 km from the city of Sorocaba, Brazil. The RMB and its associated facilities will be installed on an adjacent land to Aramar, at Km 10 of Highway Bacaetava - Sorocaba, Iperó, on a plateau 580 meters above the sea, with a total area of approximately 2 million m^2. The geographical coordinates of CEA are: 23°23'33.5"**S** and 37°47'12.4"**W**. The measurements of the background levels due to direct gamma exposure was carried out in an area with a 5 km radius around the local where the RMB will be built (area of direct influence) and in an area with 10 km radius (area of indirect influence).

1.3. Description of Equipment used to measure the background levels

The equipment used to measurement the background levels of the studied area was a Spectral Radiological Airborne Computer System (SPARCS) – portable multichannel Gamma-Ray Spectrometer designed for large volume of NaI detectors usually required in *airborne* applications or *carbone* applications of low level background. This spectrometric system collects and stores measurements of gamma radiation and has a GPS attached. It has a 2×4×16 inch NaI(Tl) crystal (2 units), and one unit of data acquisition and control (ACU telemetry). A smaller unit AT6101C (SPECTRAL RADIATION SCANNER) also known as "backpack" was used for backup purposes and also for the places where the vehicle could not reach. The instrument can be used for spectral gamma and neutron radiation scanning outdoors and indoors, carried by a person in a backpack or in a case. This unit has 512 channel MCA and Integrated GPS receiver with Gamma and Neutron detector. The *carbone/airborne* Radiological Computer System is the result of the development and integration of sophisticated radiological monitoring equipment onto a *carborne/airborne* platform.

These systems are capable of accurately detecting and, with the proper models, quantifying concentrations of specific radionuclides in the environmental. Each system acquires and records the radiometric spectra at time intervals of 1 second and each spectrum is associated with the geographic coordinates, allowing the preparation of isodose curves and also the locations or searching of natural and artificial sources of radiation. The "backpack" system has the same capabilities that SPARCS but with a lower capacity. The gamma ray method is unusual in that it requires the consideration of many factors. The source intensity and the source-detector geometry affect observed gamma ray fluency rates.

Environmental and other effects such as soil moisture, rainfall, vegetation, non-radioactive overburden, and the distribution of airborne sources of radiation all affect the measured fluency rates. This first assessment will serve to do the reconnaissance of the area and initial measurement of the background as required by Pre-Operational Radiological Monitoring Program (Preoperational PMRA)

2. METHODOLOGY

For this assessment, the *carbone* platform was used. Detectors and computer are mounted on a vehicle type truck and the whole area was covered, where there were roads or paths. When there was no way to allow the passage, the backpack unit was used. An initial survey with the car equipment was performed in Sorocaba and Iperó and outside ARAMAR. The measurement methodology was based on procedures established by Sachett [2] and further modified and applied by Souza [4, 5], and also used for venues monitoring during the XV Pan American Games in Rio de Janeiro in 2007 [6], 12th United Nations Congress on Crime Prevention and Criminal Justice- Salvador 2010, Second International Conference on Climate, Sustainability and Development in Semi-arid Regions - ICID 2010 Fortaleza and 5th CISM World Military Games – Rio 2011. This method is also applied on the measurements (*carborne* and *airborne* units) during the General Exercise for Nuclear Emergency Response carried out in Angra dos Reis-RJ. The measurement procedure consisted basically to go with the *carborne* unit in the city streets/ venues at a speed reference (10, 20, 40 or 60 km / h) selected according to traffic conditions and the frequency of acquisition of spectrum (acquisition time = 1 second). Under these conditions, the kerma associated with each point refers to a circumference of approximately 3, 6, 11 or 17 meters radius. If the area is homogeneous, the speed can be increased, but the best option is to keep the radius at 10 to 15 meters. Sometimes the type of pavement does not allow velocities bigger than 20 or 30 km/h.

Dose rates are very different to one point to another due to the natural radioactivity on soil, pavements and other building materials. Differences are always detected for different areas, with roads generally presenting lower dose rates than highly urbanized areas. Urban concentrations can present large variability, basically if the pavement is made by stone, land or asphalt and also the possibility of one kind of pavement set over the other. The presence of structures of reinforced concrete also increases the environmental dose. During the survey, the data are continuously collected and analyzed. The software RSL Mobile Cabin System shows on computer screen the current position of the unit, strip charts, a waterfall plot and the spectra display. This software also accepts maps layers. At any point the geographical positions, the kerma and the spectra are known.

A macro in Excel developed by Conti [3], convert the raw data into kerma and this value is associated with the geographical coordinates corresponding to the position. A new file with the extension *.kml* is generated and can be viewed on Google Earth program. This file is smaller in size and can be sent by any kind of wireless transfer and opened in any computer. The coordinates and value of kerma of each point are showed on computer screen. This is particularly useful to map the radiological anomalies.

3 RESULTS

The spectra of the radiometric measurements are collected at one-second intervals and positioning coordinates are synchronized with the measures through the telemetry unit. The attached spreadsheets have all the spatial data (x, y, z), the counts in each channel and the overall count in each detector. Using a macro in Excel, developed by Conti [3], data raw scores are converted into kerma associated with geographic coordinates. A new file with the extension *.kml* is generated and can be viewed on Google Earth program. Thus the region and screened-off measures can be viewed on a georeferenced map. The most modern GIS can import this data allows analysis according to the desired parameters. As an example, in Figures 1, an overview of the sector mapped, and Figures 2 to 7 shows more detailed views.

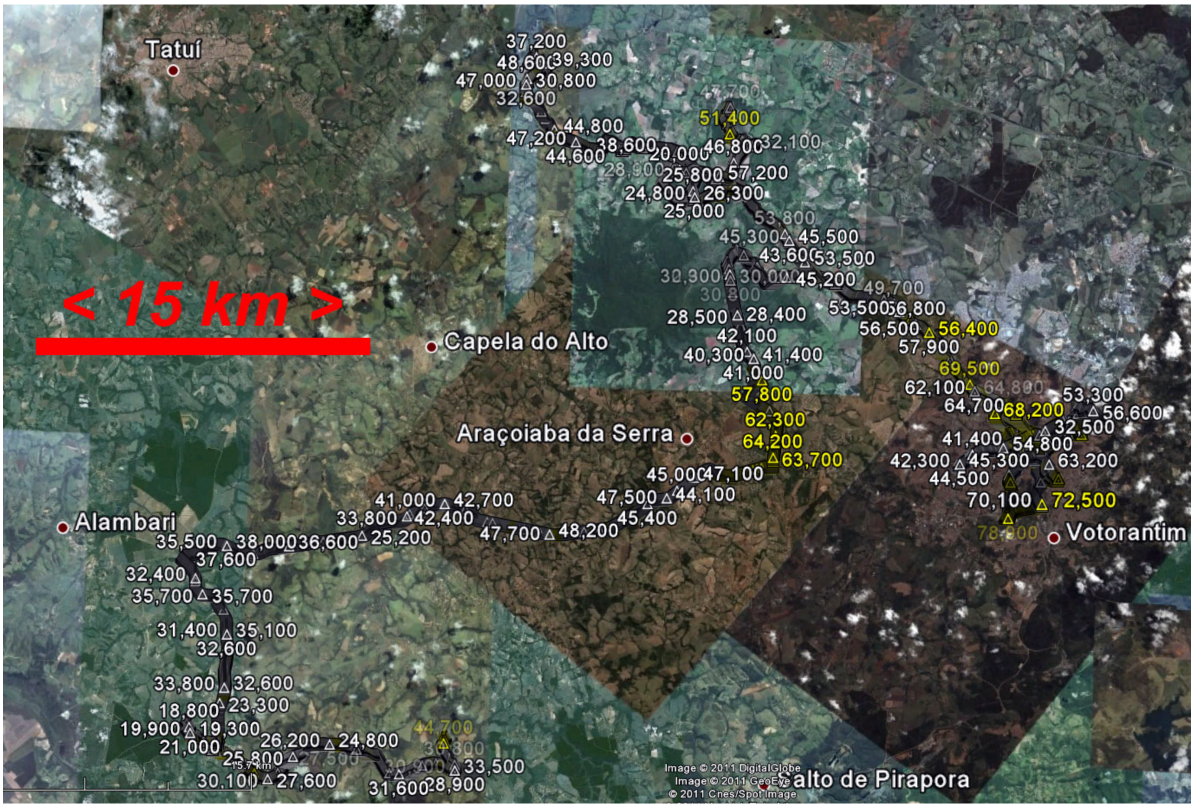

Figure 1. General area mapped. The numbers are the value of kerma at each point. Yellow numbers, mainly in the urban area, show a higher value.

Figure 2. Kerma at urban areas and rural areas

The units of kerma are nSv/h. Figure 1 shows lower numbers close to rural areas, while in urban areas the kerma values are bigger. Figure 2 shows this difference in details.

Figure 3. Access road to ARAMAR

Figure 4. Perimeter of ARAMAR facilities. This kerma values are associated to the measures inside the Aramar area. Kerma values as low as 20 nSv/h are found in area where the RMB will be installed.

Figure 5. Urban area of Iperó with closest approach, showing the pathways.

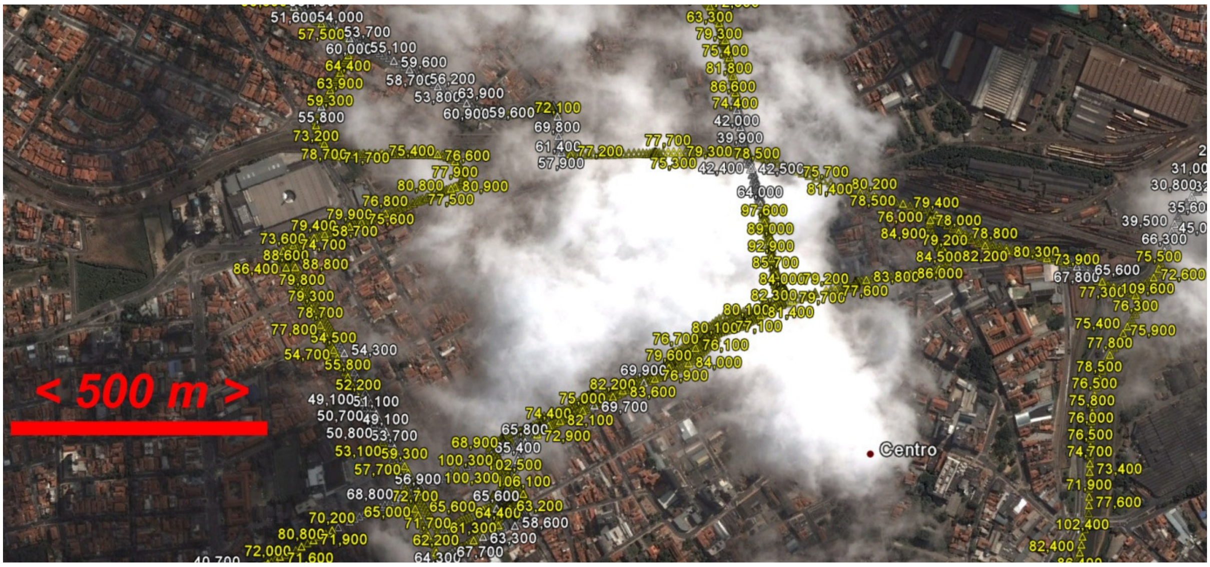

Figure 6. Central area in Sorocaba City. The kerma values are bigger due the presence of buildings and concrete structures.

Figure 7. Points near ARAMAR, the values are smaller than the urban areas, but higher than points inside the Aramar facility.

Figure 8. Sampling points, for Pre-Operational Radiological Monitoring Program, near ARAMAR.

An area of 800 km2 was monitored in a period of 5 work days. Kerma values ranging from 11 to 166 nSv/h. This data were obtained from the analysis of 80.000 spectra. Although it is not appropriate to think in general media, we can assume that the value for kerma in this whole area is very low, near to 50 nSv/h. But there is some points to mark:

- In **Figure 7**, near the Cropland we found values higher than the mean , and we suspect that this value could be associated to the use of fertilizers;
- It is not possible use a general media for kerma without consider the different pavements and use of the land;
- Even in urban area we found values very different mainly because the type and use of soil. A layer of asphalt can shield a form stone pavement decreasing the background or the same asphalt can increase the background when it was placed over land, (**Figure 5**).
- The values found inside the Aramar facility are very low, (**Figure 4**).

4 CONCLUSIONS

All sites visited in this field work proposed for the implementation of Preoperational PMRA of the RMB, were georeferenced and monitored based on measurements of gamma in situ. As shown in Figure 4, we can accept the measures done in the perimeter as a representative value for the inner places of Aramar Facility.

The values found in the measures were in line with expectations. Despite the variations shown, they are normal considering that we have different types of materials of natural origin, buildings, etc. Even the use of fertilizers, may be reasons for the differences found in rural areas (Figure 5, for example) [4].

The goal of this work is not show or presents a definitive value for kerma in Aramar Facility, because this value can change various reasons. For instance, as the initial value of background is too low, the simple installation of the physical structures of the RMB will increase the background and we cannot associate the increase as consequence of the released of any type of radioactive material.

The most important point to be noted is that this survey of the total area allow the evaluating the background levels due to direct gamma exposure before the installation of RMB. Furthers campaigns should be done to compare e verify possible differences due to new uses of the land, fertilizers, buildings and monitory the eventual releases of radionuclides.

With more data from the gamma in situ survey will be possible construct the isodose curve of the area of influence of the facility. The union of gamma in situ measures with the results of spectrometric analysis of sampled materials will allow a more precise evaluation and adjustment of models needed for emergency planning and environmental monitoring of the RMB.

Dejar dos líneas libres antes y solo una después de cada título secundario. Ellos deberán estar alineados a la izquierda y numerados como se ilustra en este ejemplo.

4. REFERENCES

[1] "Decommissiong Aspects In The Design Phase Of The Brazilian Multipurpose Reactor – RMB Paulo Ernesto De Oliveira Lainetti" Centro de Química e Meio Ambiente – CQMA INSTITUTO DE PESQUISAS ENERGÉTICAS E NUCLEARES IPEN-CNEN/SP Av. Prof. Lineu Prestes, 2242 C. Universitária São Paulo – SP, Brazil CEP- 5508-000. http://pintassilgo2.ipen.br/biblioteca/2010/eventos/15591.pdf.

[2] I. A. Sachett., "Caracterização da Radiação Gama Ambiental em Áreas Urbanas utilizando uma Unidade Móvel de Rastreamento". PhD thesis, Curso de pós-graduação em Biociências Nucleares, Instituto de Biologia, UERJ, Rio de Janeiro, 2002

[3] Conti, L.F.C, Excel Macro for Statistical Treatment Of Raw Data In Spectrometric Gamma Survey, Not Published.

[4] Souza, E.M. *et alli*- Methodological Studies for Long Range Environmental Gamma rate Survey in Brazil, Proceedings ENAN 2009, Rio de Janeiro-RJ

[5] Souza, E.M. *et alli* "Survey on background radiation in Guanabara Bay", Proceedings *INAC*, Santos, Brazil, September 30 thru October 5 2007.

[6] Nuclear Security Measures at the XV Pan American Games: Rio de Janeiro 2007, IAEA, Vienna, 2009.