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IMPLEMENTATION OF THE BRAZILIAN NATIONAL REPOSITORY

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ABSTRACT

Ionizing radiation in Brazil is used in electricity generation, medicine, industry, agriculture and for research and development purposes. All these activities can generate radioactive waste. At this point, in Brazil, the use of nuclear energy and radioisotopes justifies the construction of a national repository for radioactive wastes of low and intermediate-level. According to Federal Law No. 10308, Brazilian National Commission for Nuclear Energy (CNEN) is responsible for designing and constructing the intermediate and final storages for radioactive wastes. Additionally, a restriction on the construction of Angra 3 is that the repository is under construction until its operation start, attaining some requirements of the Brazilian Environmental Regulator (IBAMA). The RBMN Project (Repository for Low and Intermediate-Level Radioactive Wastes) aims at the implantation of a National Repository for disposal of low and intermediate-level of radiation wastes. This Project has some aspects that are unique in the Brazilian context, especially referring to the time between its construction and the end of its institutional period. This time is about 360 years, when the area will be released for unrestricted uses. It means that the Repository must be safe and secure for more than three hundred years, which is longer than half of the whole of Brazilian history. This aspect is very new for the Brazilian people, bringing a new dimension to public acceptance. Another point is this will be the first repository in South America, bringing a real challenge for the continent. The current status of the Project is summarized.

1. INTRODUCTION

In the Constitution of 1988 of Federal Republic of Brazil was established in its articles 21 and 177 that the Union has the exclusive competence for managing and handling all nuclear energy activities [1]. The Union holds the monopoly of the survey, mining, milling, exploitation and exploration of nuclear minerals, as well as of the activities related to industrialization and commerce of nuclear minerals and materials. The Union is also responsible for the final disposal of radioactive waste.

An important target of the current governmental program is to increase the participation of nuclear energy in the national electric power production, and also the use of the nuclear technology in other areas such as medicine, industry and food irradiation.

The Brazilian Ministry of Science, Technology and Innovation (MCTI) is responsible for implementing, among other targets, a Brazilian Policy for the Management of Radioactive Waste, aiming at the safe management and storage of radioactive waste generated in Brazil. Brazilian National Commission for Nuclear Energy (CNEN) is one of the institutions of

MCTI. CNEN was created in 1956 to be in charge of all nuclear activities in Brazil, including the research, development and production of radioisotopes and, according to Brazilian Legislation, also for receiving and disposing of radioactive waste from the whole country [2]. The responsibilities, and the licensing and funding processes for waste repositories were established In Brazilian law number 10.308 [3].

The guidelines and goals of Brazilian Nuclear Program (BNP) are established in Chapter 18 of the National Plan to Accelerate the Development [4], and they are reviewed in the Program for the period 2012-2015 [5]. In this Program is previewed the expansion of the use of nuclear energy and radioisotopes in different areas, especially for the medical uses and energy supply. This includes the implementation of the facilities to complete the cycle to produce the nuclear fuel, in scale able to meet domestic demand. The RBMN Project takes part of these Programs, and has the objective to implement the Brazilian Repository, where will be stored the low- and intermediate-level radioactive wastes from the whole country.

2. BRAZILIAN NUCLEAR SCENARIO

According to the IAEA Brazil, with respect to the scale of nuclear activity, belongs to Group E, “Countries with nuclear power plants and other nuclear fuel cycle facilities”, i.e. in Brazil the nuclear activities are in all areas [5].

2.1. Nuclear Power Plants

Presently, Brazil has two operating nuclear power plants (NPP): Angra 1 (640 MWe gross/ 610 MWe net, PWR) and Angra 2 (1,350 MWe gross /1,275 MWe net, PWR). A third plant, Angra 3, (1,405 MWe gross /1,330 MWe net expected, PWR) is under construction, and it is expected to begin operating in 2016. These three NPPs are located in a common site, near the city of Angra dos Reis, about 130 km of Rio de Janeiro (Fig. 1). Besides, following another Governmental decision, it has been initiated a research of possible sites all over the country for constructing new NPPs [6, 7].

Figure 1: Picture of Angra 1 and Angra 2, at Angra Reis, RJ [7]

2.2. Research Reactors

Brazil has four research reactors (RR) operating at CNEN institutes: IEA-R1, IPR-R1, IPEN/MB-01, and Argonauta.

The reactor IEA-R1 was commissioned on September 16, 1957, and it is located at the Institute for Energy and Nuclear Research (IPEN), in São Paulo city. The IPR-R1 TRIGA Mark I Reactor, located at the Nuclear Technology Development Center (CDTN), at the campus of Federal University of Minas Gerais, in Belo Horizonte, has been operating for 50 years. Argonauta Research Reactor is located at the Institute of Nuclear Engineering (IEN) on the campus of the Federal University of Rio de Janeiro, in Rio de Janeiro city. The first criticality of this reactor was reached in February of 1965. IPEN/MB-01 Research Reactor is also located at the Institute for Energy and Nuclear Research (IPEN). This one is the result of a national joint program developed by CNEN and the Brazilian Navy. These reactors are mainly used for training, radioisotope production for industrial and nuclear medicine applications, and for general irradiation services. Scientists and students from universities and other research institutions also use it for academic and technological research.

2.3. Radioactive Installations

In Brazil, the Radioactive Facilities, including the ones which use radioactive sources, are currently classified in 6 areas: medicine, industry, research and education, distribution, services and production of radiopharmaceuticals (cyclotrons). In 2011, the national registry included 4,231 Radiation Facilities. The current distribution of the facilities by the areas of application is presented in Table 1. More than a hundred new facilities have been licensed every year and it is expected that this growing trend will continue in the following years. Sources such as ^{137}Cs, ^{241}Am, ^{90}Sr, ^{60}Co, ^{226}Ra, ^{85}K and ^{241}Am/Be neutron are the most used [6].

Table 1: Distribution of radioactive installation licenses by area (2011) [6]

AREA	MEDICINE	INDUSTRY	RESEARCH	DISTRIBUTION	SERVICES	PRODUCTION (CYCLOTRONS)	TOTAL
NUMBER	1,498	1,555	822	77	264	15	4,231

2.4. Research Facilities

CNEN has six research institutes: CDTN, IPEN, IEN, LAPOC (Poços de Caldas Laboratory), CRCN-CO (Midwest Regional Center for Nuclear Sciences) and CRCN-NE (Northeast Regional Center for Nuclear Sciences), where the type of research is diverse, including nuclear physics, biology, agriculture, health, hydrology and environment. Generally, small sources of ^{3}H, ^{14}C, ^{22}Na, ^{55}Fe, ^{63}Ni, ^{125}I, ^{226}Ra, ^{35}S e ^{32}P are used for research applications [6].

3. WASTE INVENTORY

In accordance of CNEN Glossary [8] the definition of radioactive waste is: "Radioactive waste (or simply waste) is any material resulting from human activities, containing quantities of radionuclide higher than the exemption limits established by CNEN, whose reutilization is not appropriate or foreseen". The classification of radioactive wastes and the disposal options is presented in Table 2.

All the nuclear activities and use of radioisotopes in different areas produce radioactive wastes. The largest amount of wastes is generated by the NPPs, and they are classified as low and intermediate level waste. The spent fuel is not yet classified as waste, in accordance of Brazilian legislation.

Table 2: Waste classification [6]

CATEGORY	CHARACTERISTICS	DISPOSAL OPTION
1. Exempt waste.	Activity levels equal or below the exemption limits which are based on a maximum annual dose to members of the public of less than 0.01 mSv.	No radiological restriction
2. Low- and Intermediate- level waste	Activity levels above exemption limits and heat generation equal or below 2 kW/m^3	
2.1. Short lived	Limitation of long lived alpha emitting radionuclides to 4000 Bq/g in individual waste packages and to an overall average of 400 Bq/g per waste package.	Near surface repository or geological.
2.2. Long lived	Long lived radionuclide concentrations exceeding limitations for short lived waste.	Geological repository
3. High-level waste	Heat generation above 2kW/m^3 and long lived alpha emitting radionuclide concentrations exceeding limitations for short lived waste (2.1).	Geological repository

In order to determine the area of the repository, it was necessary to identify the wastes and to estimate the inventory of low- and intermediate-level radioactive wastes (LL/ILW) to be disposed. A summary of this inventory is shown in Table 3. Some assumptions had to be made to do this calculation. These assumptions were:

- Main Waste Generators:

Present: Angra 1 and Angra 2, Brazilian Nuclear Industries (INB), Research Institutes;

Future: Angra 3; Brazilian Multipurpose Reactor (RMB); four new nuclear power plants; new units of production (INB) and decommissioning.

- Repository Operation: Start: 2018; Closure: 2080.
- Nuclear Power Plants: Operation: 60 years.
- Decommissioning Wastes: Data based on the international experience.

The waste inventory values were calculated using historical data from NPPs, since the beginning of operation until now. During this estimation it was observed that with the improvement in the Waste Management (WM) activities, the wastes quantity has declined over time. The studies brought to two values for the waste volume, 39 m^3 and 57 m^3. The first ponders that the improvement in WM will continue, and the second one that no improvement will be done. Then it was considered a repository to store 60 m^3 of wastes.

TABLE 3: Estimated inventory to be disposed in the repository

ORIGIN	LL/ILW (m^3)		VERY LLRW (m^3)	TOTAL (m^3)	
	MINIMUM	MAXIMUM		MINIMUM	MAXIMUM
NPP operation	10,273	27,873	-	10,273	27,873
Other installations	1,083	1,517	-	1,083	1,517
Decommissioning	6,353	6,392	21,150	27,503	27,542
TOTAL (m^3)	17,709	35,782	21,150	**38,859**	**56,932**

4. REPOSITORY PROJECT – RBMN PROJECT

According to Federal Law No. 10308 of 20.11.2001 [3], CNEN is responsible for the design and construction of the intermediate and final storage installations. Therefore in 2008, it was launched the Project RBMN, which aims at implementing the national repository for the disposal of waste of low- and intermediate-level of radiation. CDTN is one of the R&D Institutes of CNEN, and is responsible for the technical coordination of this Project, with participants of the whole CNEN. The group that works in the Project is multidisciplinary, involving engineering, architecture, chemistry, geology, communication and other areas.

Due to the level of complexity of the project RBMN, it was necessary to establish a clear methodology based on project management and risk management, so that all goals will be achieved. Using this structured methodology to manage the Project, it is intended to avoid unexpected events during its execution, and register the complete history of the Project. As the release of the repository is forecasted to occur after three hundred years from the closure of the operational time, the methodology developed should also allow the maintenance and retrieval of all information in order to support the management of the repository by future generations.

To manage the RBMN it was established a Work Breakdown Structure (WBS) that consists in the following phases: initiation, project management, waste inventory, conceptual design, site selection, licensing, basic and detailed designs, procurement of equipment and instrument, construction, pre-operation, commissioning and closing (Fig.2). The crucial phases for the success of the Project are: conceptual design, site selection, licensing and the construction.

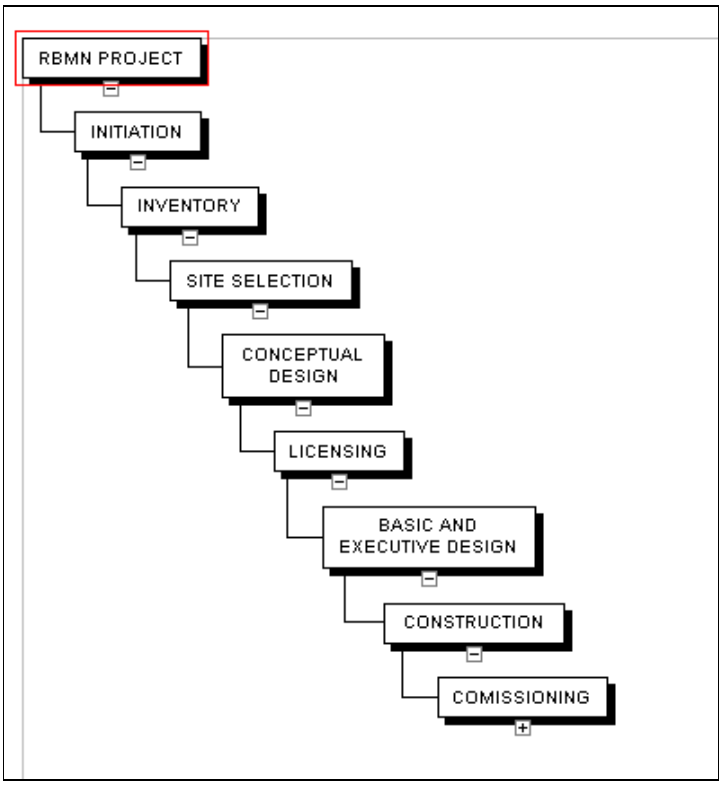

Figure 2: Simplified WBS for the RBMN Project

The waste disposal option was selected in the conceptual design phase. Many important aspects are being established, in relation to inventory, safety and protection of human beings and environment, and consequently the general acceptance criteria for the waste packages [9]. The multibarrier concept for a near-surface repository was defined for the waste disposal, a similar concept to French and Spanish repositories, L'Aube and El Cabril (Fig. 3), respectively. The estimated inventory is about 60.000 m^3 of wastes.

The site selection process for radioactive waste repositories requires a series of sequential activities as the identification of regions of interest, of preliminary areas, of potential areas and, finally, of candidate-sites. The selection should take into account 4 factors: ecological, geological, physiographic and socio-economical. These selection factors are being applied on the possible areas aiming at identifying the promising areas by excluding, accepting and/or electing criteria. As a consequence, some regions of interest for the repository were identified in Brazil. Currently the objective is to have the candidate places to begin the characterization. This task needs special attention because this Project has some aspects that are unique in the Brazilian context, especially referring to the time between its construction and the end of its institutional period.

Figure 3: Scheme of the repository – El Cabril, Spain

In accordance of Brazilian policy, the repository licensing should meet the terms of reference of the environmental licensing, which is responsibility of the Brazilian Environmental Agency (IBAMA), and the nuclear one, which is given by the Directorate for Radiation Protection and Nuclear Safety (DRS/CNEN), responsible for the evaluation of the Safety Analysis Report of the installation. This licensing process is summarized in Table 4.

Table 4: Summary of the licensing process

LICENSING		1ST. PHASE	2ND. PHASE	3TH. PHASE
ENVIRONMENTAL	License	LP Previous License	LI Installation License	LO Operation License
	Demand	Approval of the Repository site	Repository Construction	Repository Operation
NUCLEAR	Approval Certificates	CARL Site Report	CARAS Safety Analysis Report	CARFAEL Final Report of the closure analysis
	Demand	Approval of the local	Construction and Operation	Closing

After obtaining the Installation License from IBAMA and CARAS from DRS/CNEN, the construction of the repository will be made. However, site preparation and the administrative buildings may be constructed before these licenses since the operator takes the risks.

The repository will be operated for circa 60 years, and after its closure, it will start the institutional control period, previewed for 300 years, when the site will be released for unrestricted use. Consequently the studies should propose design as well procedures to assure that during all this time the facility will meet the safety requirements. During all the phases of RBMN Project the procedures should be prepared, so that when the construction of the repository will be finished, all procedures will be ready for its commissioning and operation. This approach is very important, since the staff will change many times until the end of the institutional control.

CNEN intends to have international external technical support for developing the most complex tasks of the repository and some efforts has been made in this direction with companies that operate repositories in other countries.

5. CHALLENGES

As the closure of the repository is forecasted for more than hundreds of years, the developed methodology will allow the record and retrieval of all information in such a way to support the Repository management by oncoming generations. This time is about 360 years, when the area will be released for unrestricted uses. It means that the Repository must be safe and secure for more than three hundred years, which is longer than half of the whole of Brazilian history. This aspect is very new for the Brazilian people, bringing a new dimension to public acceptance. Another point is this will be the first repository in South America, bringing a real challenge for the continent. Then it is being very carefully to treat the subject, in order to avoid difficulties concerned to the public acceptance.

Another challenge is to implement this facility after the scenario brought by the events of in Fukushima that are still on people mind. A great effort is being made to explain the differences between a NPP and a repository. Being the first repository in Brazil for wastes with several radionuclides, and the first to be licensed for this purpose, this Project will bring uniqueness to the nuclear and environmental licensing agencies, presenting an additional challenge for these stakeholders. Beyond these it will be necessary optimize the resources and the time, associated to the quality in order to give confidence to all stakeholders.

6. CONCLUSION

The RBMN Project is part of the national solution for the storage of radioactive waste generated by the use of radioisotopes and nuclear energy in Brazil. It aims at implementing the national repository for the disposal of waste of low- and intermediate-level of radiation. The inventory includes the wastes from the NPP operation, nuclear fuel cycle installations

and from the use of radionuclides in medicine, industry, environment and R&D activities. Material classified as NORM and TENORM is not foreseen to be stored in this repository.

The Repository should meet the requirements of IBAMA and DRS, and also answer the questions raised by the stakeholders. It is necessary to work with transparency within the legal base, in a way that doesn't compromise the technical work. The discussion with the municipalities, where the repository will be installed, may require political negotiations, and certainly hearings, that will affect the schedule.

RBMN Project success will be translated by obtaining the commissioning and full acceptance and satisfaction of all involved, meaning that all expected results and benefits were produced.

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