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PRELIMINARY EVALUATION OF A NEUTRON CALIBRATION LABORATORY

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ABSTRACT

In the past few years, Brazil and several other countries in Latin America have experimented a great demand for the calibration of neutron detectors, mainly due to the increase in oil prospection and extraction. The only laboratory for calibration of neutron detectors in Brazil is localized at the Institute for Radioprotection and Dosimetry (IRD/CNEN), Rio de Janeiro, which is part of the IAEA SSDL network. This laboratory is the national standard laboratory in Brazil. With the increase in the demand for the calibration of neutron detectors, there is a need for another calibration services. In this context, the Calibration Laboratory of IPEN/CNEN, São Paulo, which already offers calibration services of radiation detectors with standard X, gamma, beta and alpha beams, has recently projected a new calibration laboratory for neutron detectors. In this work, the ambient equivalent dose rate (H*(10)) was evaluated in several positions inside and around this laboratory, using Monte Carlo simulation (MCNP5 code), in order to verify the adequateness of the shielding. The obtained results showed that the shielding is effective, and that this is a low-cost methodology to improve the safety of the workers and evaluate the total staff workload.

1. INTRODUCTION

Currently, there is an increase on the activity of the oil sector, medical applications and scientific research employing neutron sources, which leads to an increased demand for radiological monitoring services. Thus, it is necessary to develop tools and methods to ensure the reliability of radiation measurements. Ii this sense, the first step is to ensure the precision and accuracy of the instruments [1] by means of a proper calibration process. In Brazil, according to the CNEN NE 3:02 standard, the calibration is compulsory, and must be carried out by authorized entities [2].

In Brazil, there is only one calibration laboratory for neutron detectors, located at the National Laboratory for Metrology of Ionizing Radiation (LNMR-IRD/CNEN, Rio de Janeiro). This laboratory is also the only Secondary Standard Dosimetry Laboratory in Latin America which offers this kind of service, thus with a high load of services per year.

In order to expand the calibration services for neutron detectors, in this work the shielding project for a new laboratory for calibration of neutron detectors was evaluated by means of Monte Carlo (MC) simulations. They were carried out to evaluate the possibility of using an already existent room as the house for the new technical activity. MC calculations in radiological protection [3] present the advantage of a low cost technique that allows the detailed study of the laboratory under evaluation including geometrical set-ups and material selections. The MC code MCNP5 [4] was employed, and a detailed geometrical description of the laboratory was used during the simulations.

2. MATERIALS AND METHODS

2.1. Calibration laboratory characteristics

A simplified floor plan of the Neutron Calibration Laboratory at IPEN is shown in Fig. 1.

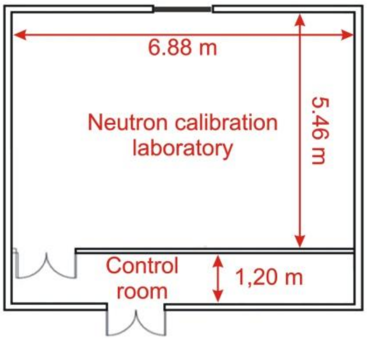

Figure 1: Simplified floor plan of the Neutron Calibration Laboratory at IPEN.

The laboratory is located in a Bunker, and it presents walls of concrete with 15.0 cm thickness covered with 2.5 cm thick plates of drywall, with the exception of the control room wall, which is made entirely of two drywall plates with 1.25 cm thickness, separated by a 9.0 cm thick air layer. There are also two wooden doors with 3.4 cm thickness and a back door of a source storage room, with 2.0 cm thickness of lead covered with two iron layers of 3.0 cm thickness. The ceiling is made of concrete and the floor of granite.

For a more realistic simulation, the surrounding areas were also incorporated to the geometrical arrangement. Neutron scattering may occur in these areas, causing alterations on the spectrum. The laboratory is surrounded by earth on the right side, behind the sources storage room, and in part of the left side. Other positions are composed of atmospheric air.

2.2. Radioactive source

The neutron source used in this laboratory is a ^{241}Am-Be, calibrated at the Brazilian Secondary Standard Dosimetry Laboratory (IRD), with an activity of 1 Ci and an emission rate of 2.46×10^{6} s^{-1}, manufactured by the Amersham International Ltda. The source has a double shielding of inox stainless steel. The external shielding dimensions are 31.0 mm in length and 22.4 mm in diameter. The active region has, approximately, 17.5 mm in length and 17.5 mm diameter. This source was positioned in a PVC support with 88.54 cm hight.

2.3. Monte Carlo simulation

The Neutron Calibration Laboratory at IPEN was simulated with the MCNP5 Monte Carlo code [4]. This code was developed, and it is maintained by the Los Alamos National Laboratory (USA). It is a multipurpose code that may be used to transport (or is a coupled transport of) neutrons, photons and electrons.

The geometry employed during the simulations was based on the floor plan and measurements, in order to guarantee that all dimensions were in accordance with the existent laboratory. The material description was also utilized according to the laboratory data. Its insertion on the MCNP code was based on the PNNL-15870 report [5].

All geometry dimensions (laboratory and surrounding areas) were inserted in a 150.0 m radii sphere. The neutron spectrum was stored in energy bins following the fluence to dose conversion coefficients from the ICRP report [6]. The ^{241}AmBe source was simulated at the exact position where it will remain for the future use .

3. RESULTS

The geometry used during the simulations is shown in Figs. 2, 3 and 4. The measurement points were chosen in order to evaluate the doses from the ^{241}AmBe source in several different positions: an adjacent laboratory (point 1), in the source room (point 2), a laboratory located upstairs (point 3), a street located at the upstairs level (point 4), the control room (point 5) and the corridor in front of the control room (point 6).

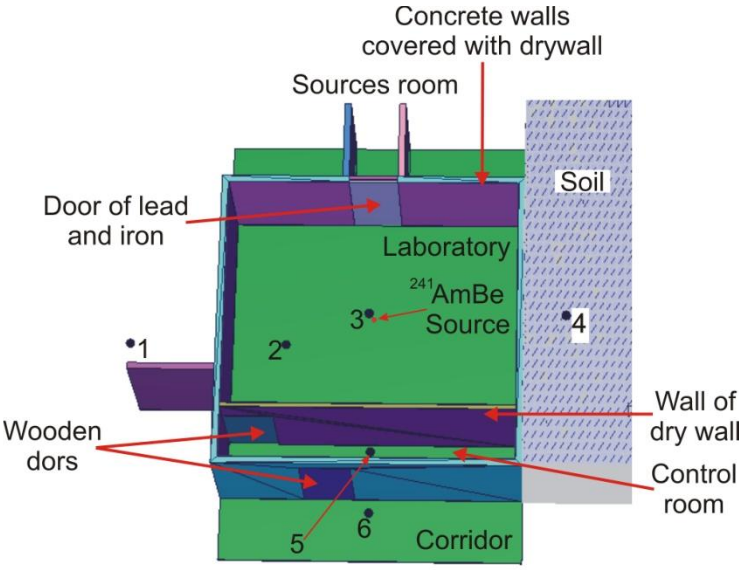

Figure 2: Neutron Calibration Laboratory Geometry used during the simulations with the measurement points.

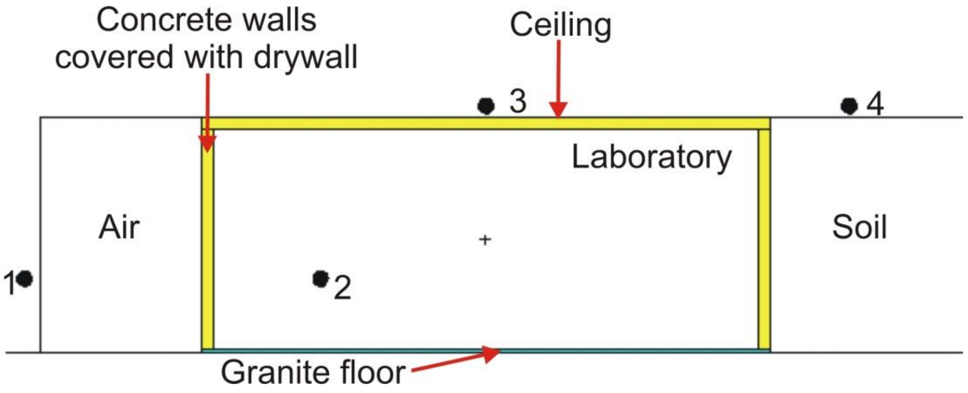

Figure 3: Axial view of the Neutron Calibration Laboratory Geometry used during the simulations with the measurement points (the ^{241}AmBe source is not visible in this plot).

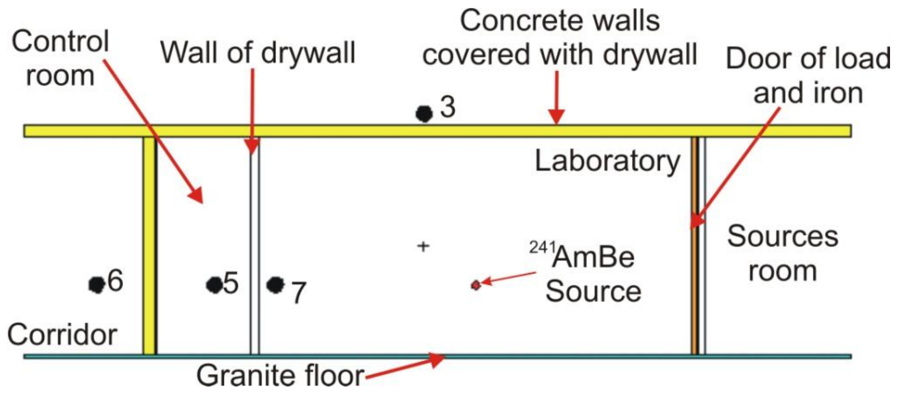

Figure 4: Lateral view of the Neutron Calibration Laboratory Geometry used during the simulations with the measurement points.

The results from the simulations are listed in Table 1. To obtain these values, the responses from the MC simulations were converted to dose using the ICRP fluence to dose conversion coefficients [6], and the values were normalized in relation to an experimental measurement at point 5. This measurement was obtained in controlled conditions, using an equipment calibrated for H*(10).

Table 1: H*(10) values simulated (for neutrons) obtained in several points at the Neutron Calibration Laboratory of the IPEN

Point of measurement	H*(10) (μSv/h)
1	0.0004
2	0.4825
3	0.1677
4	0.0025
5	0.2000
6	0.0405

According to Brazilian regulations, the areas must be characterized for general public and workers. If an area is characterized for public, the annual dose limit must be within 1 mSv, and if it is for workers, this limit is 20 mSv. These are the upper limits, and the doses to workers and public must be optimized, according to the ALARA principle. Several regulations and specific rules apply for each type of area, and more details may be found elsewhere [2].

For this new laboratory, areas 1, 3, 4 and 6 are considered for public. Considering a full occupation of the adjacent laboratories, points 1 and 3, the doses for a 8 h/day workload will be up to 0.8 µSv/year and 0.3 mSv/year respectively, which are well within the acceptable limits. These values are much lower for areas 4 and 6 where the occupation is about 1/16 of the laboratories.

Areas 2 and 5 are considered for workers. In this scenario, considering an unrealistic workload of 8h/day the doses would come up to 0.4 mSv/year which is also well within the limit (20 mSv/year). Area 2 is not intended to be accessed with the source exposed, and this might only occur in the case of an accident. Even in such a case the doses are expected to be low.

Considering all these facts, the results from Table 1 show that the shielding of the laboratory is suitable for the neutron source used to calibrate the dosimeters, and the workers may use the control room safely during the calibration procedures.

Furthermore, the room selected to house the Neutron Calibration Laboratory will not need any further shielding project, which could increase the costs for its installation. More measurements will be taken in a near future, in order to validate the results presented in this work. The main differences that may appear are related to the description of the materials used during the simulations. The values from PNNL-15870 [5] are an approximation of the materials used in the laboratory, but the errors from these differences will be evaluated in the future.

4. CONCLUSIONS

In this work, the shielding of the new Neutron Calibration Laboratory of IPEN was evaluated using Monte Carlo simulations with the MCNP5 code. The results obtained show that the shielding is effective, and that this is a low-cost methodology to improve the safety of the workers and to evaluate the total stall workload. A more detailed evaluation of the differences between the composition of the materials presented in PNNL-15870 and the materials used in the laboratory must be carried out once the laboratory set-ups are completed.

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