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ACTIVITY DETERMINATION OF THE Am-241 SOURCES FROM RADIOACTIVE LIGHTNING RODS

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ABSTRACT

The authorization for manufacture commerce and installation of radioactive lightning rods, in Brazil, was lifted in 1989 by the National Nuclear Energy Commission – CNEN (Resolution nº 4/89). Since this date, these devices have been replaced and have been sent to the Institutes subordinated to the CNEN, amongst them the Nuclear and Energy Research Institute – IPEN-CNEN/SP. Radioactive Waste Management Laboratory – RWML of the IPEN - CNEN/SP had received, approximately, 16,000 units up to the end of 2008. The radioactive lightning rod is constituted in its majority, for a central metallic rod, where two or three metallic plates are mounted. In these plates, on average, six Am-241 sources are fixed. The process used for the radioactive lightning rods treatment is the dismantling of the device and the withdrawal of the sources from the metallic plates. The activity values of the lightning rods sources, supplied by the manufacturers, vary from two to three orders of magnitude and therefore it is necessary to characterize these sources. This paper describes the methodology used to measure the actual activity of each Am-241 sources extracted from the radioactive lightning rods. The first step was to sample tens of Am-241 sources and carry out the activity measurements for further use in the system calibration. The equipment used in this first stage was a gamma spectrometer, previously calibrated with an Am-241 standard source, in agreement with the same arrangement and same geometry in the measures of the sources. Results show that there are sources with similar activity values of those supplied by the manufacturers, but there are also sources with no activity – or also activity very low compared with the expected value –, as well as sources contend other radionuclides.

1. INTRODUCTION

The radioactive lightning rods containing Am-241 sources began to be manufactured in Brazil, at the beginning of the 1970s, but the National Nuclear Energy Commission (CNEN) suspended the authorization for its manufacture and installation in 1989, through RESOLUTION NO. 4 / 89 [1], for reasons related to the normative justification of practices under the basic principles of radiological protection [2]. These devices began to be replaced by conventional systems without radioactive sources and referred to treatment as radioactive waste, to the institutes of the CNEN.

The Nuclear and Energy Research Institute (IPEN-CNEN/SP) is the principal place of receipt and management of such waste, which until May of 2009 received 16,196 units, 15,888 of those containing sources of Am-241 and 308 of Ra-226 [3], in a total of 75,000 manufactured – estimated by CNEN out of information from the manufacturers.

The lightning rods – both radioactive and conventional – are made of three parts: an air terminal, a conductor and an earth ground, but the air terminal of the radioactive rod contains the radioactive sources and has its geometry modified compared to the conventional one, for the accommodation of the radioactive element. This air terminal is made, mostly for two or three metal discs that contain on average three sources each [3]. Thus, the average activity for lightning rods ranges from 25 to 92 MBq. Figure 1 presents a picture of a typical radioactive lightning rod.

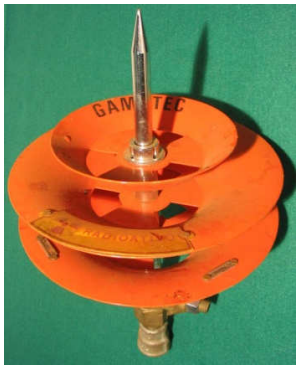

Figure 1. Radioactive lightning rods containing Am-241 sources.

The sources of Am-241 fixed in the air terminals vary in geometry and unit activity, but most of them have rectangular tape shape of about 20 mm by 12.5 mm. The source, before being fixed to the support source, is covered by a thin layer of gold and has as a support base, a strip of steel with 0.002 mm thick each; this set is riveted or welded to the structure of the air terminal [4].

Most radioactive lightning rods contain Am-241 sources, but there is a non specified amount that contains Ra-226 sources, about 1%.

The Am-241 has atomic number 95 and is an artificial element of the actinide series obtained from the decay of Pu-241 in a nuclear reactor. This radionuclide has a half-life of 432.7 ± 0.5 years and gamma emission energy of 59.54 keV [5]. It is classified as an element of high toxicity when ingested or inhaled due to its alpha emission.

The process used for the treatment of radioactive lightning rods is the dismantling of devices, that means they are demounted in the Glove Box and its parts are decontaminated or routed to temporary storage, and the sources contained in their metal discs are set aside for later storage and final deposition together with the other sealed sources.

In order to be accepted for disposal, radioactive sources must be characterized and, therefore, it is necessary to determine the activity of the Am-241 contained in each lightening rod to keep an inventory of sources. The figures provided by the manufacturers are average values and can vary significantly, two to three orders of magnitude.

This study aims to measure the real activity of sources of Am-241 radioactive lightning rods received for the treatment by the Radioactive Waste Management Laboratory (RWML) of IPEN in order to confirm or not whether the figures provided by the manufacturer meets the requirements established by the competent authority regarding to radioisotopic inventory.

In 2008, the development of a methodology for characterization of Am-241 sources in lightning rods was started at IPEN. The initial step was the selection of dozens of sources strips and the determination the activity of each of them.

The equipment used to achieve this first step was a gamma spectrometer, which is capable of providing the activity of each radioisotope in the source by the number of counts in peak energy of the line gamma range of interest shown in the spectrum. This equipment was previously calibrated with a standard Am-241 source, using the same arrangement and the same geometry used in the measurements of sources.

2. MATERIALS AND METHODS

The Am-241 sources selected are pressed in the Glove Box to be almost flat – because they became twisted after the dismantling of the lightning rods – to improve its management and results of the measurement of its activity. Subsequently they are bagged individually and numbered, so they won't contaminate the measurement equipment.

The gamma spectrometer used consists of a detector Hiperpure Germanium (HPGe), model GX2518, with 25% efficiency, connected to an amplifier and a source of high tension of Canberra, and uses a multichannel Accuspec and the computer system named Genie 2000.

The calibration of the gamma spectrometer is performed with a measurement of a standard Am-241 source.

The default font used was measured in the Nuclear Metrology Laboratory (NML) of the Research Reactor Center of IPEN, being the sample number NR-1, by the certificate of calibration of radioactive sources no. AI-22/2002, at the reference date of 01/11/2002. The system of measure adopted was a detector of HPGe calibrated with standard radioactive source of International Atomic Energy Agency (IAEA). The activity of the pattern Am-241 source calculated by the NML was of 6.00 MBq, with uncertainty of 2.3% (with 68% of confidence level) and this activity was determined assuming a coverage of 0.001 mm of gold on the layer of Am-241.

The default source is fixed to the bottom of a bottle, and the positions of the source and the attenuator on stainless steel plates (of 1.6 mm and 2.0 mm thick) inside the equipment are defined so that the dead time in measurements is the smallest possible.

To determine the minimum period of time necessary for the measurement of the samples, the activity of a single Am-241 source was measured at different time intervals, to find out if there is any significant change in the results.

The activity of each of the 192 encapsulated sources, following the same geometry and arrangement of the previously determined positions, were measured.

3. RESULTS AND ANALYSIS

The data of the default font of Am-241 are presented in Table 1.

Table 1. Value of the activity of the default font of Am-241 and its uncertainty

Standard Am-241 source	Activity (MBq)	Uncertainty (%)
NR-1	6.00	2.3

The positions of the attenuators and the source extent to be defined from optimization of dead time are shown in Table 2.

Table 2. Positions of the attenuators and the source of the equipment on the shelves

	Attenuator (1.6 mm)	Attenuator (2.0 mm)	Source
Shelve	2	3	20

The activity of the source number 23, chosen randomly, was measured, within periods of 200 seconds, ranging from 200 to 2,000. These values are shown in Table 3.

Table 3. Value of the activities of sample no. 23, Am-241 source calculated in the time between 200 and 2,000 s, ranging up to 200 s, and their uncertainties

Time (s)	Activity (MBq)	Uncertainty (%)
200	7.963	0.35
400	7.957	0.25
600	7.971	0.20
800	7.946	0.17
1,000	7.939	0.16
1,200	7.977	0.14
1,400	7.987	0.13
1,600	7.978	0.12
1,800	7.978	0.12
2,000	7.966	0.11

Since the uncertainty values, in activity, are not greater than 0.35%, it can be argued that there is no need for longer periods of time for each measurement and the chosen period of 200 s is adequate.

Performing the measurement with the Am-241 sources in pre-determined positions for the materials involved and with the gamma-spectrometer calibrated, for a period of 200 seconds each, the following distribution values of the activities of these sources were obtained.

Some of the sources used to measure show activity less than 10^4 Bq, which can be explained by a deficiency in the deposition of the radionuclide during the manufacturing process of the source or yet, by the possible use of stripes without Am-241 in the assembly of the lightning rods. This fact is shown in the first column of the histogram in Figure 2.

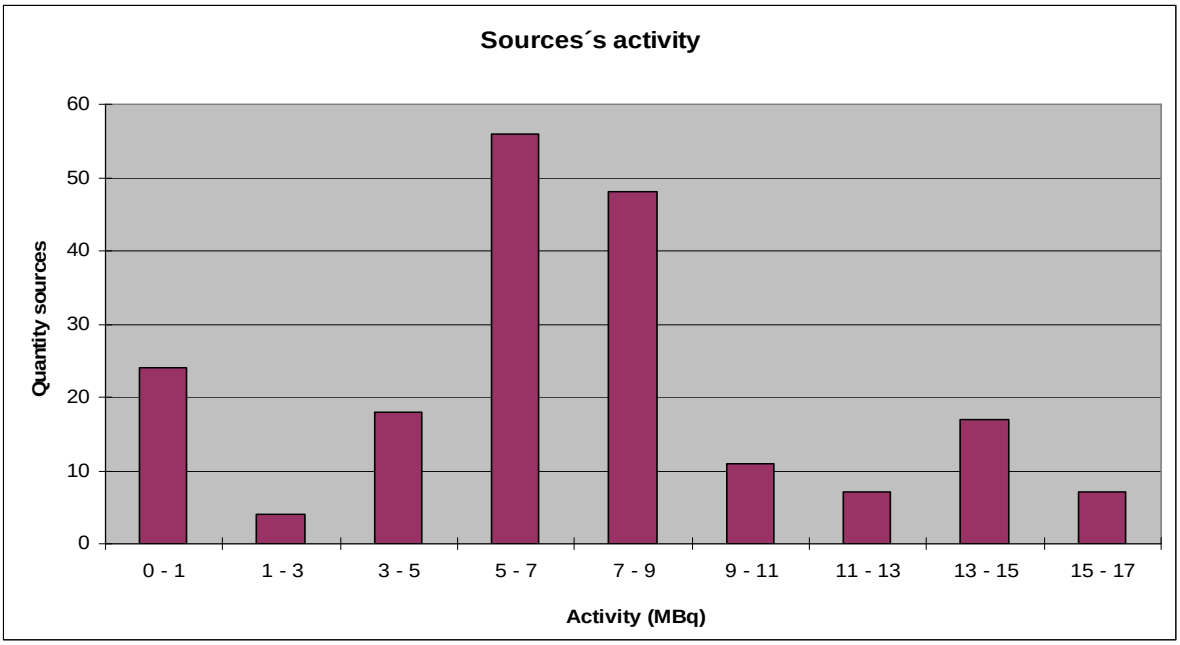

Figure 2. Distribution of obtained values for the activity, in intervals of 2 MBq, of the sources of lightning rods measured.

Values in the intervals 1 to 5 MBq and of 9 to 17 MBq can be interpreted as being caused by some conditions as manufacture of the source, setting of the lightning rods, or it can be outside the specified dimensions. The values of the first interval may also be due to loss of containment where the radioactive material may have been removed.

The average real value of the activity is 7.1 ± 4.1 MBq and the mean activity calculated with the exclusion of less than 10^4 Bq is 8.1 ± 3.3 MBq, which shows that the exclusion of these values would not be significant for the calculation of average activity, as the variation is about 13%.

The calculation of uncertainties in the activities was done with the equation of standard deviation [6].

4. CONCLUSIONS

The value calculated for the average activity (7.1 ± 4.1 MBq) of the 192 sources of radioactive lightning rods is in agreement with the data supplied by manufacturers that varies from 4.2 to 15.3 MBq.

This range could be obtained considering that the average activity for lightning rods varies from 25 to 92 MBq and that the most common is to find six sources per device. The explanation why this range is so wide can be given by the great variation in the values of total activity for lightning rods, and the fact that the number of sources per device varies from two to eight. This means that it's not possible to assure that the activity contained in the sources be a fixed number including the amount of variables involved since the manufacturing process of the source to final product.

Some sources have much lower values of activity than the others (less than 10^4 Bq) due to probable variations in the process of manufacture of the source or of the lightning rod. And others, have values outside the range of 6 to 9 MBq which may be from the non-uniformity of the deposit of radioactive material in the manufacture of the source, or yet, the loss of this material, in the case of values below this range.

It is necessary the assessment of a higher number of sources to check if the sample is representative with respect to the supply of cards that do not contain radioactive material deposited – in this case is around 12.5%.

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