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CHARACTERIZATION OF THE WATER FILTERS CARTRIDGES FROM THE IEA-R1 REACTOR USING THE MONTE CARLO METHOD

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ABSTRACT

Filter cartridges are part of the primary water treatment system of the IEA-R1 Research Reactor and, when saturated, they are replaced and become radioactive waste. The IEA-R1 is located at the Nuclear and Energy Research Institute (IPEN), in Sao Paulo, Brazil. The primary characterization is the main step of the radioactive waste management in which the physical, chemical and radiological properties are determined. It is a very important step because the information obtained in this moment enables the choice of the appropriate management process and the definition of final disposal options. In this paper, it is presented a non-destructive method for primary characterization, using the Monte Carlo method associated with the gamma spectrometry. Gamma spectrometry allows the identification of radionuclides and their activity values. The detection efficiency is an important parameter, which is related to the photon energy, detector geometry and the matrix of the sample to be analyzed. Due to the difficult to obtain a standard source with the same geometry of the filter cartridge, another technique is necessary to calibrate the detector. The technique described in this paper uses the Monte Carlo method for primary characterization of the IEA-R1 filter cartridges.

1. INTRODUCTION

Filter cartridges are part of the primary water treatment system of the IEA-R1 Research Reactor at the Nuclear and Energy Research Institute (IPEN), located in São Paulo, Brazil. It is a pool-type reactor, operating at 5 MW and fueled with uranium enriched to 20% in ^{235}U, in which the water is demineralized by a filtration system [1]. The water cleaning system is composed of two banks with six filter cartridges each one, two mixed ion-exchange resin beds and two activated charcoal beds [2]. The filter cartridges are replaced when they present high pressure-drop and low flow, becoming radioactive wastes that are sent to the Radioactive Waste Management Department (GRR) for treatment and storage.

The management of radioactive waste has several steps, and the primary characterization is a very important stage, in which the physical, chemical and radiological data of the wastes are obtained, and therefore the appropriate treatment can be defined according to the acceptance criteria for final disposal [3].

There are a lot of techniques such as the radiometry ones, mathematical modeling (Monte Carlo method) and radiochemical that can be used to obtain physical, chemical and radiological information [4, 5, 6]. The choice of the technique depends on some factors as the type of radiation to be measured and the physical state of the radioactive waste. In the primary characterization are made several analyses in the radioactive waste in order to determine the radionuclides, their activities and exposure rate.

Gamma spectrometry can be used for the radionuclide identification in the filter cartridges and the activities values. In this technique, the efficiency calibration is an important parameter and it can be obtained using sources with known activities or by mathematical simulation using the Monte Carlo method (MC) [7, 8].

The use of the Monte Carlo method is an alternative to perform the detector efficiency calibration due to the difficult to obtain a standard calibration source in the same geometry of the filter cartridges, and to avoid the generation of radioactive waste [9, 10].

The Monte Carlo method simulates the transport of radiation in systems of complex geometry in a simplified manner using random numbers for sampling of the probability distribution functions [11]. The code used in this paper for the calculation of the transport of radiation, based on the Monte Carlo method, is the Monte Carlo N-Particle Transport (MCNP), having cross-section libraries for neutrons, photons and electrons [12].

2. METHODS AND MATERIALS

In this paper it was used the gamma spectrometry analysis associated with the simulation by the Monte Carlo method.

For the gamma spectrometry analysis it was used a germanium hyperpure detector, model EGPC-15-190-R, manufactured by Eurisy. It is a coaxial and P-type detector with an active volume of 63.32 cm^3 and it has an intrinsic efficiency of 15%. The associated electronics consists on a multichannel analyzer, model Multiport II from Canberra, and the data acquisition system is performed by the Genie 2000 software [13].

The filter cartridge is made of polypropylene, with density of 0.95 $g.cm^{-3}$, porosity of 10 μm and, it has a cylindrical shape, whose dimensions are presented in Figure 1.

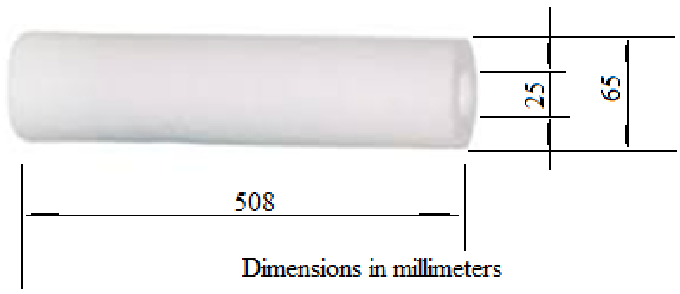

Figure 1: Filter cartridge from the IEA-R1 reactor

The analysis of the filter cartridge was performed using gamma spectrometry with the source-detector distance of 55 cm. The code used to simulate the experimental setup was the MCNP-4C and, it was considered a filter like a source containing the radionuclide ^{152}Eu.

The tally used in the simulation was the F8 that performs the calculation of the pulse height distribution, with the p mode that indicates the transport of photons [14], and the number of photons was in the order of 10^9.

The theoretical efficiency values obtained in the simulation were used as the input data into the Genie 2000 software in order to get the efficiency calibration for the system detector-filter [13].

The primary characterization of the filter cartridge was made by identifying the radionuclides and by estimating their respective activities using the efficiency calibration obtained by the Monte Carlo method using Equation 1,

$$A = \frac{A_p}{I_\gamma . \varepsilon_{mcnp} . T} \tag{1}$$

A is the activity, in Bq, A_p is the net count of the peak area, I_γ is the probability of gamma ray emission, ε_{MCNP} is the calculated efficiency, and T is the counting time, given in s.

3. RESULTS

The experimental gamma energy spectrum that was obtained with one of the measured filters and the radionuclides identified is presented in Figure 2.

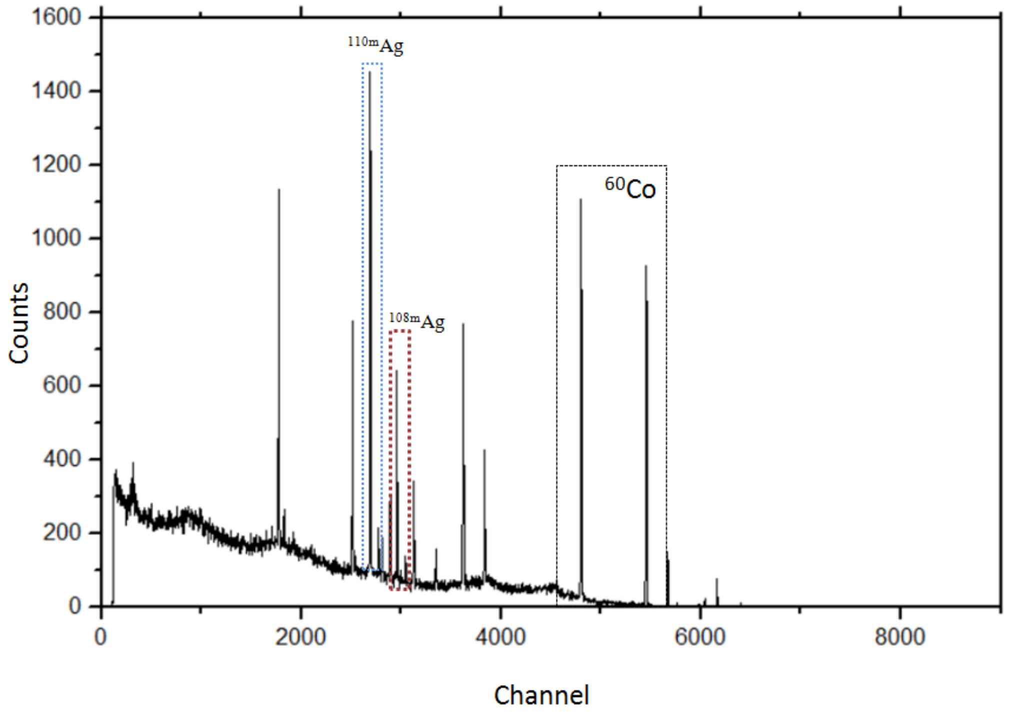

Figure 2: Typical gamma spectrum of cartridge filters

The activities of the identified radionuclides were calculated using the Equation 1 and the values of energy and net peak area from the output report file generated by the Genie2000 software are presented in Table 1.

Table 1: Energy and net peak area from the spectrum

Energy (keV)	FWHM (keV)	Net Peak Area	Net Area Uncert.	Continuum Counts
34.02	5.19	8.20E+003	91.05	0.00E+000
71.73	7.16	7.04E+003	148.87	0.00E+000
78.48	7.16	8.96E+003	216.91	0.00E+000
85.76	7.16	6.30E+003	215.53	0.00E+000
122.48	10.48	6.86E+003	43.30	0.00E+000
433.82	4.19	1.30E+004	114.41	0.00E+000
446.56	9.85	5.90E+003	99.23	0.00E+000
614.17	3.62	8.42E+003	92.54	0.00E+000
620.72	3.62	2.56E+003	52.05	0.00E+000
657.74	2.54	1.40E+004	118.64	0.00E+000
677.29	7.38	4.68E+003	74.16	0.00E+000
687.21	7.38	3.79E+003	70.95	0.00E+000
706.75	5.59	4.37E+003	66.55	0.00E+000
722.87	3.09	6.83E+003	82.72	0.00E+000
744.10	8.21	2.86E+003	57.05	0.00E+000
763.89	3.74	3.96E+003	63.04	0.00E+000
818.24	7.72	2.69E+003	55.28	0.00E+000
833.57	8.34	1.19E+003	63.52	0.00E+000
884.71	2.80	8.31E+003	91.29	0.00E+000
937.42	4.89	5.27E+003	74.96	0.00E+000
944.81	4.89	1.58E+003	44.24	0.00E+000
1168.23	2.48	4.61E+002	22.01	0.00E+000
1173.08	2.48	1.13E+004	106.77	0.00E+000
1177.97	2.47	4.04E+002	20.89	0.00E+000
1313.05	3.36	1.30E+002	11.70	0.00E+000
1332.41	2.47	9.61E+003	98.06	0.00E+000
1384.26	2.41	1.45E+003	38.13	0.00E+000

Based on the obtained results it was possible to identify three radionuclides presents in the filter cartridge: ^{108m}Ag, ^{110m}Ag and ^{60}Co [4, 6], with the total estimated activity value in the order of units of MBq [6].

3. CONCLUSIONS

The use of the Monte Carlo method to obtain the detector efficiency calibration associated with the gamma spectrometry is very helpful for the primary characterization, allowing estimating the activity values and identifying the radionuclides presents in the filter cartridge.

The Monte Carlo method has the advantage of being a nondestructive technique, which allows that the same sample can be measured repeatedly and to avoid the generation of radioactive waste.

This work represents an important contribution in the primary characterization of the filter cartridge from the IEA-R1 research reactor, allowing to determine the appropriated treatment of this radioactive waste stream.

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