X Congreso Regional Latinoamericano IRPA de Protección y Seguridad Radiológica
"Radioprotección: Nuevos Desafíos para un Mundo en Evolución"
Buenos Aires, 12 al 17 de abril, 2015
SOCIEDAD ARGENTINA DE RADIOPROTECCIÓN

CALIBRATION OF IN VITRO BIOASSAY METHODOLOGY FOR DETERMINATION OF ^{131}I IN URINE

Carvalho, C.B.[1], Hazin, C.[1,2] and Lima, F.F.[2]

[1] Departamento de Energia Nuclear, Universidade Federal de Pernambuco, Brazil
[2] Centro Regional de Ciências Nucleares do Nordeste, Comissão Nacional de Energia Nuclear, Brazil

.

ABSTRACT

The use of unsealed radioactive sources in institutions practicing Nuclear Medicine poses a significant risk of internal exposure of workers. In this context, handling of ^{131}I plays an important role in relation to other radionuclides due to its wide application, particularly in medical diagnosis and therapy of diseases related to the thyroid gland. Given the increasing number of services using ^{131}I in their examination protocols, the probability of accidental incorporation of this radionuclide has increased. The present study aimed to implement methodologies for in vitro bioassay at the Centro Regional de Ciências Nucleares do Nordeste (CRCN-NE/CNEN), Recife, Brazil, for internal monitoring of individuals occupationally exposed to ^{131}I. For in vitro system calibration, a coaxial HPGe detector model GC1018 and a standard ^{133}Ba source were used. Upon obtaining the calibration factor, it was possible to determine the minimum detectable activities (MDA) for the system by using direct measurements of distilled water simulating urine (in vitro). Then, by using the biokinetic models provided by the International Commission on Radiological Protection, edited with the AIDE software version 6.0, it was possible to estimate the Minimum Detectable Effective Dose (MDED). MDED values obtained were compared to the record level of 1 mSv recommended by the International Atomic Energy Agency in the urine compartment 24 h. The values found were lower than the record level of 1 mSv in all simulated incorporation scenarios: inhalation of vapor and particles with AMAD of 1 μm and 5 μm, type F compound, and ingestion. The results of this work show that the implemented technique is suitable for conducting internal monitoring of workers to ^{131}I. It is intended to continue the work aiming the monitoring of occupationally exposed individuals from Nuclear Medicine Services in Recife, Brazil.

1. INTRODUCTION

The use of radioactive isotope ^{131}I is widespread in Nuclear Medicine by having affinity with the thyroid gland and its emission properties of gamma and beta radiation are useful both for diagnosis and treatment of patients with pathologies that are related to this gland. According to data published by the Committee United Nations Scientific on the Effects of Atomic Radiation (UNSCEAR), ninety percent of the therapeutic procedures in nuclear medicine uses ^{131}I [1].

As the routine handling of unsealed sources represents a significant risk of chronic internal exposure of workers involved in this activity, the International Atomic Energy Agency (IAEA) recommends the implementation of internal monitoring programs for employees [2].

Brazil currently has 429 nuclear medicine services authorized by the National Nuclear Energy Commission (CNEN) and about 380 perform procedures involving use of ^{131}I [3].

[1] E-mail del Autor. fflima@cnen.gov.br

Other issues, justify the need to implement routine internal monitoring programs in new centers, such as the continental dimensions of Brazil, which prevents the monitoring is concentrated in some CNEN units located in the Southeast; the amount of nuclear medicine services authorized by CNEN that increases every year; the number of occupationally exposed individuals; and the monitoring frequency for the ^{131}I recommended by the International Commission on Radiological Protection (ICRP) in its publication 78, which at least fortnightly [4].

The present study aimed to implement methodologies for *in vitro* bioassay at the Centro Regional de Ciências Nucleares do Nordeste (CRCN-NE/CNEN), Recife, Brazil, for internal monitoring of individuals occupationally exposed to ^{131}I.

2. MATERIALS AND METHODS

The *in vitro* bioassay technique was conducted in the Laboratório de Medidas de Atividade de Radionuclídeos at CRCN-NE/CNEN. The measurements were performed with the HPGe coaxial GC1018 detector coupled to Genie 2000 software. In addition, urine was chosen as a biological sample because it is the main excretion route of ^{131}I and also it is easier to be collected, analyzed and interpreted.

2.1. Calibration of the Detection System

The calibration of the detection system HPGe coaxial was performed with a ^{133}Ba standard liquid source (38.2Bq on 09/13/2010) and the counting geometry was standardized using a graduated polyethylene container as presented in Figure 1. Sample volumes up to 2000 ml were chosen in order to obtain appropriate sensitivity even in a small incorporation of ^{131}I. It is noteworthy that the source of ^{133}Ba was used by emitting photons of 356keV, similar to the ^{131}I energy (364keV) with a proper longer half-life.

Figure 1. Graduated polyethylene container (2000 ml) used to standardize the counting geometry of *in vitro* bioassay method.

The ^{133}Ba source was diluted with 100 ml of distilled water and homogenized at the polyethylene container. It was placed in contact with the coaxial HPGe detector and to obtain the average counting rate, 20 measurements with a 10 minute counting were performed. The

subsequent measurements were made by adding 100 ml aliquots of distilled water until the maximum volume of 2000 ml.

Detection efficiencies were calculated for each volume between 100 and 2000 ml from the different energies of the emitted photons by ^{133}Ba. The detection efficiency of the photon 364keV from ^{131}I in each volume was obtained by interpolation of efficiency x energy curve obtained with the standard ^{133}Ba source. The calculation of efficiency was performed by using Equation 1 [5].

$$\varepsilon = \dot{C} / A \times P_{\gamma} \quad (1)$$

Where:
ε is the detection efficiency for photons energy; $\dot{C}$ is the net count rate, in s^{-1}; A is the activity of ^{133}Ba, in Bq; Pγ is gamma emission intensity.

2.2. Determination of MDA, MDI and MDED

For the determination of minimum detectable activity (MDA), spectra of the solution of distilled water in the polyethylene container were used to simulate the urine of an unexposed individual. The measurements were performed starting with an initial volume of 100 ml and then by adding 100 ml until reaching the maximum volume of 2000 ml. Each measurement lasted 10 minutes. MDA values were given in terms of the sample volume and calculated from Equation 2 [6].

$$MDA = (3 + 4.65\sqrt{B}) / \varepsilon \times T_C \quad (2)$$

Where: MDA is the minimum detectable activity, in Bq; B is the total count of the distilled water; ε is the detection efficiency, in min-1.Bq-1; and T_c is the counting time, in minutes.

The minimum detectable effective dose (MDED), which evaluates the detection sensitivity of the developed technique, was calculated by editing the ^{131}I biokinetic model provided by ICRP 78 [4] using the AIDE software (version 6.0) [7]. This software calculates retention and excretion fractions of activity in a particular compartment/organ as a function of time (t) after incorporation, m(t)j, and also calculates the dose coefficients, e(50)j, for different types and incorporation scenarios. Thus, the MDED was calculated using Equations 3 and 4 [8].

$$MDI = MDA / m(t)_j \quad (3)$$

$$MDED = MDI / e(50)_j \quad (4)$$

Where: MDI is the minimum detectable incorporation, in Bq; MDA is the minimum detectable activity, in Bq; m(t) is the retention and excretion fraction of activity retained in a

particular compartment/organ at a time (t) after incorporation, in $Bq.Bq^{-1}$; MDED is the minimum detectable effective dose, in Sv; and $e(50)_j$ is the dose coefficient for the evaluated incorporation scenario, in $Sv.Bq^{-1}$.

It is noteworthy that, to calculate the values of IMD and DEMD from AMD values, the incorporation scenario that was chosen: inhalation as the main entry route of ^{131}I in the body, single incorporation and compound in vapor form. This scenario was chosen because it is the most common form of incorporation of ^{131}I in the body. Since the recording level recommended by IAEA is 1 mSv [2], the detection sensitivity (MDED) of the technique developed should be less than or equal to this value.

3. RESULTS

3.1. Calibration Detection System

From the results of the measurements performed by detection system using the standard ^{133}Ba source with a 10-minute counting time, calibration curves were obtained for each sample volume measured by simulating the urine. Figure 2 shows one of the calibration curves relating the efficiency and energy.

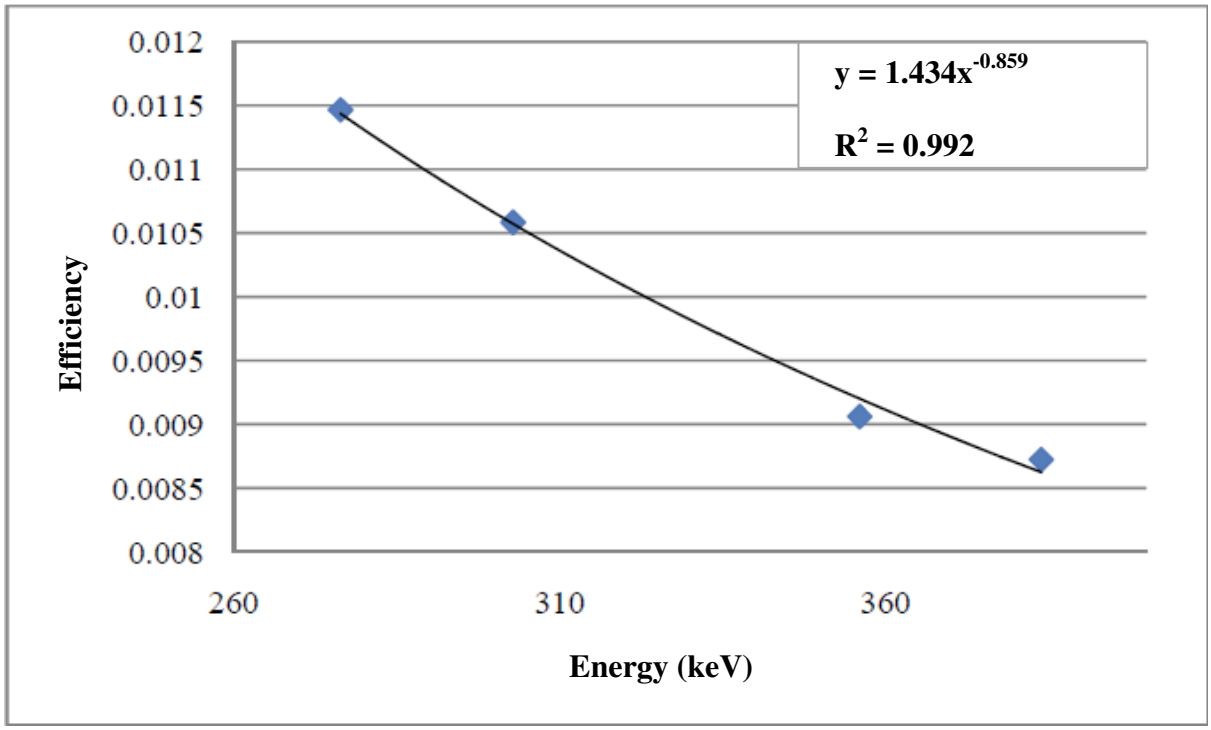

Figure 2. Efficiency x Energy calibration curve for 600ml geometry

Using the calibration curves equations and substituting the x value with the main energy value of ^{131}I (364keV), it was possible to develop an efficiency curve in relation to the volume of urine (Figure 3). Through this efficiency curve, ^{131}I may be detected in urine samples in accordance with the collected volume.

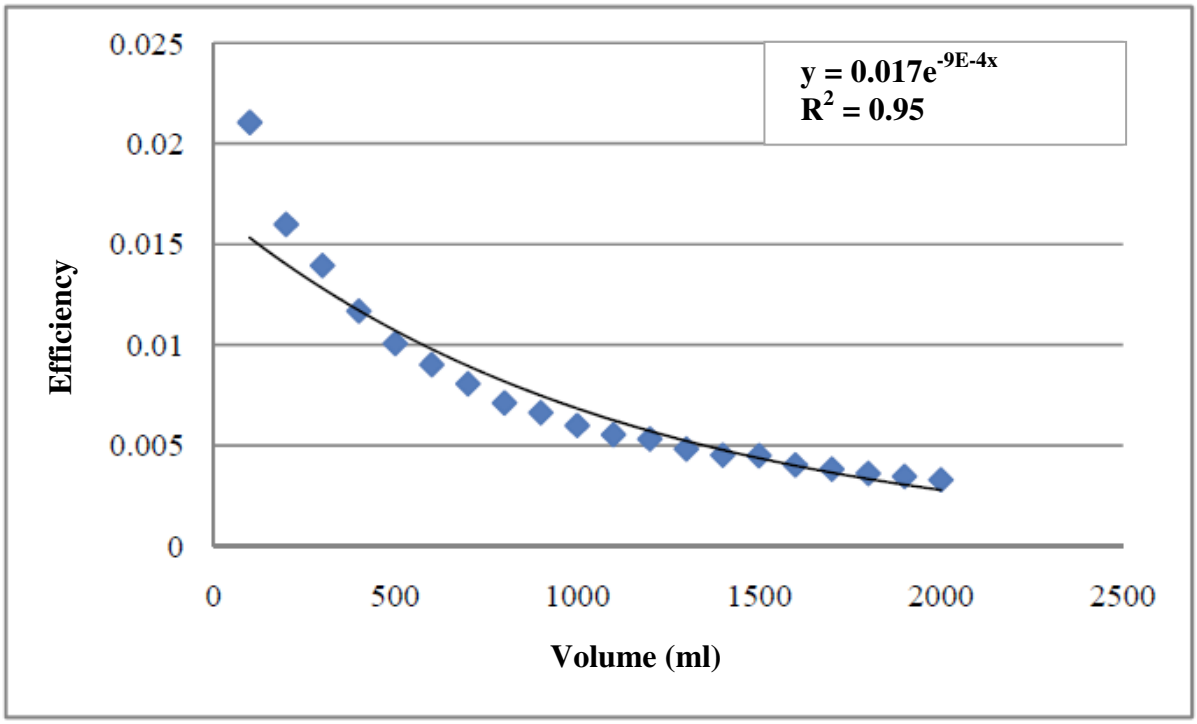

Figure 3. Efficiency curve in relation to the ^{131}I sample volume

3.2. Determination of MDA, MDI and MDED

Table 1 shows the values obtained to MDA, MDI and MDED calculated for the measurement system utilized in this work and described on Materials and Methods section. For the chosen incorporation scenario, it was considered the dose coefficient, $e(50)=2.0\times10^{-8}$ Sv/Bq, and the greater value of excretion fraction in urine compartment, $m(t) = 5.27 \times 10^{-1}$ Bq.Bq^{-1}.

It was observed that the minimal detectable activity by the system obtained was 4.8Bq, resulting in minimum detectable effective dose of 0.18 μSv to the volume of 2000 ml. These results show that the measurement system is sufficiently sensitive to detect doses beneath the minimum recommended by the IAEA (1 mSv) [2].

4. CONCLUSIONES

The *in vitro* internal monitoring method for evaluation of ^{131}I developed in the Laboratório de Medidas de Atividade de Radionuclídeos at CRCN-NE/CNEN shows proper sensitivity for internal occupational monitoring, since it is possible to detect doses beneath 1 mSv, as recommended by IAEA. Then, the implemented technique is suitable for conducting internal monitoring of workers to ^{131}I.

It is intended to continue the work aiming the monitoring of occupationally exposed individuals from Nuclear Medicine Services in Recife, Brazil.

Table 1. : MDA, MDI and MDED for different volumes on the polyethylene container geometry obtained by the efficiency curve

Volume (ml)	MDA (Bq)	MDI (Bq)	MDED (Sv)
100	0.8	1.4	2.9×10^{-8}
200	1.0	1.9	3.8×10^{-8}
300	1.1	2.2	4.3×10^{-8}
400	1.4	2.6	5.2×10^{-8}
500	1.6	3.0	6.0×10^{-8}
600	1.8	3.4	6.7×10^{-8}
700	2.0	3.8	7.5×10^{-8}
800	2.2	4.3	8.5×10^{-8}
900	2.4	4.6	9.1×10^{-8}
1000	2.7	5.1	1.0×10^{-7}
1100	2.9	5.5	1.1×10^{-7}
1200	3.0	5.7	1.1×10^{-7}
1300	3.3	6.3	1.3×10^{-7}
1400	3.5	6.7	1.3×10^{-7}
1500	3.6	6.7	1.3×10^{-7}
1600	4.0	7.5	1.5×10^{-7}
1700	4.2	7.9	1.6×10^{-7}
1800	4.4	8.4	1.7×10^{-7}
1900	4.6	8.8	1.8×10^{-7}
2000	4.8	9.2	1.8×10^{-7}

5. REFERENCIAS

1. United Nation Scientific Committee on the Effects of Atomic Radiation – UNSCEAR, *Report to the General Assembly with scientific annexes,* Vienna (2000).
2. International Atomic Energy Agency – IAEA, *Assessment of Occupational Exposure Due to Intakes of Radionuclides - Safety Guide , nº RS-G-1.2*,Vienna (1999).
3. Comissão Nacional de Energia Nuclear, http://www.cnen.gov.br (2014).
4. International Commission on Radiological Protection - ICRP, *Individual Monitoring for Internal Exposure of Workers - ICRP Publication 78*, Oxford (1997).
5. Gilmore, G., *Practical Gamma-ray Spectometry*. 2. ed. John Wiley & Sons, Ltd, London (2008).

6. Health Physics Society, “Performance Criteria for Radiobioassay”, *HPS N13.30*, McLean (1996).
7. Bertelli, L., Melo, D. R., Lipsztein, J., Cruz-Suarez, R., “AIDE: Internal Dosimetry Software”, *Radiation Protection Dosimetry*, **130(3)**, pp. 358–367 (2008).
8. Oliveira, C. M., Lima, F. F., Oliveira, M. L., Silva, T. V., Dantas, A. L., Dantas, B. M., Alonso, T. C., Silva, T. A., “Evaluationof a technique for in vivo internal monitoring of ^{18}F within a Brazilian laboratory network”, *Radiation Protection Dosimetry*, **153 (1)**, pp. 100-105 (2013).

ACKNOWLEDGMENTS

The authors are thankful to *Instituto Nacional de Ciência e Tecnologia em Metrologia das Radiações em Medicina* (INCT) and to the *Comissão Nacional de Energia Nuclear* (CNEN).