

# A portable detection system for *in vivo* monitoring of $^{131}\text{I}$ in routine and emergency situations

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**Abstract:** *In vivo* monitoring of  $^{131}\text{I}$  in human thyroid is often used to evaluate occupational exposure in nuclear medicine facilities and in the case of accidental intakes in nuclear power plants for the monitoring of workers and population. The device presented in this work consists on a Pb-collimated NaI(Tl)3”x3” detector assembled on a tripod and connected to a portable PC. The evaluation of the applicability and limitations of the system is based on the estimation of the committed effective doses associated to the minimum detectable activities in different facilities. The system is suitable for use in routine and accidental situations.

**Keywords:** Nuclear instrumentation, Bioassay, Internal monitoring, iodine-131

## 1. INTRODUCTION

$^{131}\text{I}$  plays an important role in radiation protection since it is widely used in Nuclear Medicine and is one of the radionuclides of interest in the case of accidents and incidents in nuclear power plants. It is highly volatile and radiotoxic, which may represent a radiological hazard, especially in places where significant activities are present in the workplace and in the environment. In such situations, inhalation should be the main pathway of internal exposure.

According to the IAEA, a monitoring program for workers occupationally exposed to  $^{131}\text{I}$  may include direct thyroid measurement, indirect bioassay of urine samples and workplace monitoring [1].

This work presents a methodology developed for *in vivo* monitoring of internal contamination using a NaI(Tl)3”x3” scintillation detector

system installed in a lead collimator and assembled on a tripod.

## 2. METHODOLOGY

### 2.1 Calibration procedures

The calibration procedures were carried out in four medical facilities located in the city of Rio de Janeiro and at the IRD Whole Body Counter Laboratory.

The NaI crystal is collimated with a 9 mm lead cylinder aimed to reduce ambient background and increase sensitivity up to a level suitable for internal monitoring of occupationally exposed workers. The detector signal output is connected to a compact electronic module which includes the whole electronics (HV power supplier, preamplifier, shaping amplifier, gain stabilizer, ADC and MCA). The whole system is powered through a USB port and spectrum

acquisition and processing is controlled by Genie 2000 Basic Spectroscopy Software installed in a portable PC [2].

The neck-thyroid phantom used for the calibration of the detection system was designed and produced at the In Vivo Monitoring Laboratory of IRD [3]. It contains a known activity of  $^{133}\text{Ba}$  ( $^{131}\text{I}$  simulator) standard solution, uniformly distributed on the surface of a filter paper previously cut in the form and shape of a human thyroid (Fig. 1). Besides the emission characteristics of the radionuclide of interest, the design and production of the phantom must consider the biokinetic of the element in the human body [4] in order to simulate the real distribution in the whole body or in specific organs and tissues [5].



**Figure 1. Neck-thyroid phantom developed at IRD**

The monitoring protocol (including count time and geometry) was optimized in each facility in order to achieve a balance between sensitivity and comfort for the individual. Thus, the neck-

thyroid phantom was measured in a series of distances between 14.5 to 25 cm. Although the shorter the distance the higher the counting efficiency, *in vivo* measurements performed too close to the body should be avoided in order to overcome morphological differences between the phantom and an actual human organ.

The calibration setup was identical to the counting geometry established for *in vivo* monitoring as shown in Figure 2.



**Figure 2. *In Vivo* measurement of  $^{131}\text{I}$  in the thyroid, using a Pb-collimated NaI(Tl)3x3 installed on a tripod in Lab 1**

It should also be highlighted that the application of a monitoring protocol should always result in minimum disturbance in routine activities, especially in the case of medical facilities.

### 2.2 Evaluation of the sensitivity of the technique

The evaluation of the sensitivity is based on the calculation of the minimum detectable activity (MDA) and the corresponding minimum detectable intake (MDI) and the minimum detectable effective dose (MDED). The MDA is based on the Publication ISO12790-1 [6] and is calculated as shown on equation (1):

$$MDA = \frac{4.65\sqrt{N}}{CF \times T} + \frac{3}{CF \times T} \quad (1)$$

Where: N = Total counts of the background; CF=Calibration Factor (cps/Bq) and T = count time.

The Minimum Detectable Intake (MDI), is a function of the MDA and depends on the biokinetic of the element, the exposure scenario and time elapsed between intake and measurement. It is calculated as shown on Equation (2):

$$MDI = MDA / m(t)_{inh} \quad (2)$$

Where: MDA = Minimum Detectable Activity (Bq) and m(t) = Retention fraction by inhalation.

The last parameter to be calculated is the Minimum Detectable Effective Dose. It is based on the MDI and in the dose coefficient, e(g), associated to the corresponding intake scenario

adopted in the simulation. It is calculated as shown on Equation (3):

$$MDED(Bq) = MDI \times e(g)_{inh} \quad (3)$$

Where: MDI = Minimum Detectable Intake (Bq) and e(g)<sub>inh</sub> = Dose coefficients (mSv/Bq).

In this work it has been used m(t) values corresponding to 1 day after the intake and the dose coefficient, e(g), corresponding to volatile iodine in the form of gas.

The standard biokinetic and dosimetric values are available in the Publication 78 of the ICRP [4] and can also be generated for specific exposure scenarios and times through the software AIDE [7].

### 3. RESULTS AND DISCUSSION

Table 1 presents the results of the measurements in terms of Calibration Factor, Minimum Detectable Activity and Minimum Detectable Effective Dose obtained.

**Table 1. Calibration Factors and Sensitivity of the portable NaI(Tl)3"x3" detector system assembled on a tripod (Values of Minimum Detectable Effective Doses were calculated for measurements performed 7 and 14 days after the intake).**

Facility	Room Type	<sup>1</sup> D (cm)	<sup>2</sup> CF (cpm/Bq)	<sup>3</sup> MDA (Bq)	<sup>4</sup> MDED (x 10 <sup>-2</sup> mSv)	
					7 days	14 days
<b>Hospital 1</b>	Examination room	23.0	0.18 ± 0.01	296	4.22	8.18
<b>Hospital 1</b>	Office	23.0	0.18 ± 0.01	266	3.80	7.34
<b>Hospital 2</b>	Shadow-shield	14.5	0.33 ± 0.01	136	1.94	3.76
<b>Hospital 3</b>	Examination room	23.0	0.18 ± 0.01	326	4.66	9.00
<b>Hospital 4</b>	Office	23.0	0.18 ± 0.01	386	5.52	10.70
<b>Lab 1</b>	Lead-Shielded Room	20.0	0.24 ± 0.01	226	3.22	6.24
<b>Lab 2</b>	Mobile Lab	20.0	0.22 ± 0.01	163	2.32	4.50
<b>Lab 2</b>	Mobile Lab	25.0	0.15 ± 0.01	168	2.40	4.64
<b>Lab 3</b>	Whole Body Counter	20.0	0.15 ± 0.01	51	0.73	1.41

<sup>1</sup>D = Distance; <sup>2</sup>CF = Calibration factor; <sup>3</sup>MDA = Minimum Detectable Activity; <sup>4</sup>MDED = Minimum Detectable Effective Dose

The distance of 14.5 cm in Hospital B, where a shadow-shield is available, was defined due to detector support and shielding characteristics. In this case, the detector is positioned in a fixed distance in relation to the neck-thyroid phantom as compared with other facilities.

The highest sensitivity was obtained in Laboratory 3, where a heavy shielded whole body counter facility is available, allowing to achieve a lower background count rate as compared to the other facilities where calibrations were performed in conventional rooms.

#### 4. CONCLUSIONS

The Minimum Detectable Effective Doses (MDED) for the *in vivo* measurement of  $^{131}\text{I}$  in the thyroid obtained at different facilities using a Pb-collimated  $\text{NaI(Tl)}3''\times3''$  detector assembled on a tripod, in 20 minutes count time, is far below the recording level of 1 mSv.

Such statement is valid for an exposure scenario considering a single inhalation of  $^{131}\text{I}$  vapor and measurements performed up to 14 days after the intake. It should be noted that the count time can be reduced to a certain minimum value depending on local background, providing more comfort to the subject. However, such reduction is limited to the increase in the MDED up to a maximum value suitable for internal monitoring in a routine basis or in accident situations.

This work provides a useful, simple and cost-effective method to evaluate  $^{131}\text{I}$  incorporation. The methodology can be implemented routinely in Nuclear Medicine Services as well as in emergency situation in order to estimate the committed effective doses associated to the internal exposed of workers and public.

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#### 5. REFERENCES

- [1] IAEA – International Atomic Energy Agency. Safety Standards Series – “Assessment of Occupational Exposure due to Intakes of Radionuclides” - Safety Guide No. RS-G-1.2, (1999).
- [2] [http://www.canberra.com/products/radiochemistry\\_lab/digital-signal-processing.asp](http://www.canberra.com/products/radiochemistry_lab/digital-signal-processing.asp) (2017)
- [3] Dantas, B. M.; Dantas, A. L. A.; Cruz-Suarez, R. IAEA intercomparison exercises of thyroid measurement: Performance of Latin American and Caribbean laboratories. Radiation Protection Dosimetry. , v.170, p.455 - 69, (2015).
- [4] ICRP - International Commission on Radiological Protection. Individual Monitoring for Internal Exposure of Workers. Publication 78, (1998)
- [5] ICRU – International Commission on Radiation Units . Phantoms and computational models in Therapy, Diagnosis and Protection. ICRU Publication 48 (1992)
- [6] ISO – International Standard Organization. Radiation Protection – Performance Criteria for Radiobioassay. Part 1: General principals - ISO 12790-1 (2001)
- [7] Bertelli L, Melo DR, Lipsztein J, Cruz-Suarez R. AIDE: Internal Dosimetry Software. Radiation Protection Dosimetry 130, n. 3: 358–367; (2008).