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EXPERIMENTAL RESULTS FOR THE VALIDATION OF THE IODINE-131 MONITORING METHOD IN THYROID

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Abstract. Whole Body Monitoring Laboratory (WBML) has a long tradition in performing internal contamination assessments for gamma emitting radionuclide intakes, in accordance with its own Quality Assurance System that respects the requirements of the specific national and international standards, regulations and guidelines in the field [1-3]. The method implemented for I-131 monitoring in thyroid was applied in a case of an internal contamination through ingestion. The assessments were made using a Thyroid Counter equipped with a lead shielded NaI(Tl) detector for the thyroid, with an efficiency of 0.9×10^{-2} counts/Bq*s and MDA of 34 Bq for I-131. The results obtained after the selection and processing of the measurement data showed a good compliance of them with the model considered for the retention of the iodine in the thyroid, after an intake through ingestion, specified in ICRP78 [4].

Key words: I-131, thyroid, monitoring, ingestion, dosimetry.

1. INTRODUCTION

The WBML is notified to execute: (1) the monitoring of internal contamination for workers involved in nuclear activities from hospitals, industry, research, national security, with potential risk of internal exposure to ionizing radiation, and in case of nuclear accident, for persons belonging to the public; (2) the estimation of gamma emitting radionuclide intakes; (3) the estimation of committed effective doses.

In the period 2000–2009, in WBML were performed 5240 internal contamination assessments that reveal intakes with different radionuclides, as Co-60, Tc99m, Zn-65, I-125, I-131, Cs-134, Cs-137 and Ir-192, specific to different types of nuclear activities, as production of radiopharmaceuticals, production of sealed sources, nuclear medicine, cyclotron maintenance and research activities. From these, 16% represents thyroid measurements for the estimation of I-131 intakes and committed effective doses. During a series of routine monitoring of workers, it was

identified one case of internal exposure that was not an occupational intake, but the result of the ingestion of a capsule of I-131 used in the diagnosis of a thyroid disease. The value of intake was known by the physician that prescribed the diagnosis procedure, but unknown to the Whole Body Monitoring Laboratory. Because it was possible, there were performed eight thyroid assessments, at different intervals after intake, namely, in the days 39, 42, 45, 49, 73, 85, 95, 98 after intake, to see the compliance with the expected decay for the I-131 in the thyroid.

2. MATERIALS AND METHODS

The equipment approved by the National Commission for Nuclear Activities Control, the Romanian competent authority in the nuclear field, to be used in WBML, for the thyroid internal contamination assessment with I-131, is a Thyroid Counter, a gamma spectrometer, equipped with a lead shielded NaI(Tl) scintillation detector of 40 mm diameter, and 50 mm thickness.

The efficiency calibration was performed with a plexiglass thyroid phantom, simulating the adult thyroid anatomical shape and volume, filled with certified radioactive solution of known activity of I-131. The values determined for the efficiency and for the Minimum Detectable Amount were of 0.9×10-2 counts/Bq*s and of 34 Bq for I-131 (364keV), respectively.

The associated electronics of detectors consists on state-of-art analog and digital ORTEC equipments and for spectra acquisition is used the software Gamma Vision 32 supplied, also, by ORTEC.

The intake and the effective dose estimation were made following the steps suggested in the new document, IDEAS - General Guidelines for the Estimation of the Committed Effective Dose from Incorporation Monitoring Data [5], for acute ingestion. All these steps are parts of different stages of intake and effective dose evaluation implemented in a flowing chart that establishes, clearly, any action to be done for an optimum estimation of the intake and of the committed effective dose.

The stages followed were:

Stage 1. Check for need of evaluation

Stage 2. Check on significance of a new measurement and consistency with previous evaluation

Stage 3-4. Identification of pathway of intake for special evaluation

Stage 6. Special procedure for ingestion

The stage 5 was skipped because it is dealing with the special evaluation of radionuclide inhalation.

The evaluation procedure of the intake and effective dose is not very simple because the monitoring values indicate an important internal exposure and there are necessary many steps of evaluation, just to be sure that it is applied the quality assurance of data for reliable results.

3. RESULTS

The thyroid retention predicted values (Bq per Bq intake) following an acute ingestion of I-131 were considered those from the ICRP 78.

Stage 1. It was identified the first monitoring value and determined M_c = 3.8 Bq, the critical monitoring quantity using the formula:

$$M_C = \frac{0.1\text{mSv} \times \text{m(T/2)}}{e(50)} \times \frac{T}{365},$$

where: 0.1 mSv = annual effective committed dose, considered as dose level such that lower doses are not evaluated for the purpose of the monitoring programme; T= monitoring interval for the first monitoring value; $m(T/2)$ = retention function for the monitoring quantity at a time $t = T/2$; $e(50)$ = effective dose coefficient.

Stage 2.

(i) It was determined the order of magnitude of the intake and of E(50) from the first measurement data.

Intake = 3397143 Bq
$E(50)$ = 73.75 mSv.

(ii) There were considered realistic estimates of the overall uncertainty on each data point expressed as a total scattering factor, SF, taking into account the total uncertainties of type A and type B [6]. IDEAS Guidelines assume that the overall uncertainty can be described by a lognormal distribution and the scattering factor SF is defined as the geometric standard deviation, as follows :

$$(\ln \text{SF})^2 = \ln^2(\text{SF}_\text{A}) + \ln^2(\text{SF}_\text{B}),$$

where SF_A=1.07 and SF_B=1.15 are total uncertainties of type A and type B, applicable for *in vivo* measurements and suggested by IDEAS Guidelines.

Stage 3-4. It was decided that it was necessary to perform a special monitoring for a case of pure ingestion.

Stage 6. There were analyzed the monitoring data to see the compliance with the iodine model for ingestion declared in ICRP78 and to look for outliers.

The monitoring data M(i) and the trend of data considering the thyroid retention predicted values (Bq per Bq intake) m(t) following an acute ingestion (I = 3 397 143 Bq) of I-131 from the ICRP 78 were represented in Fig.1.

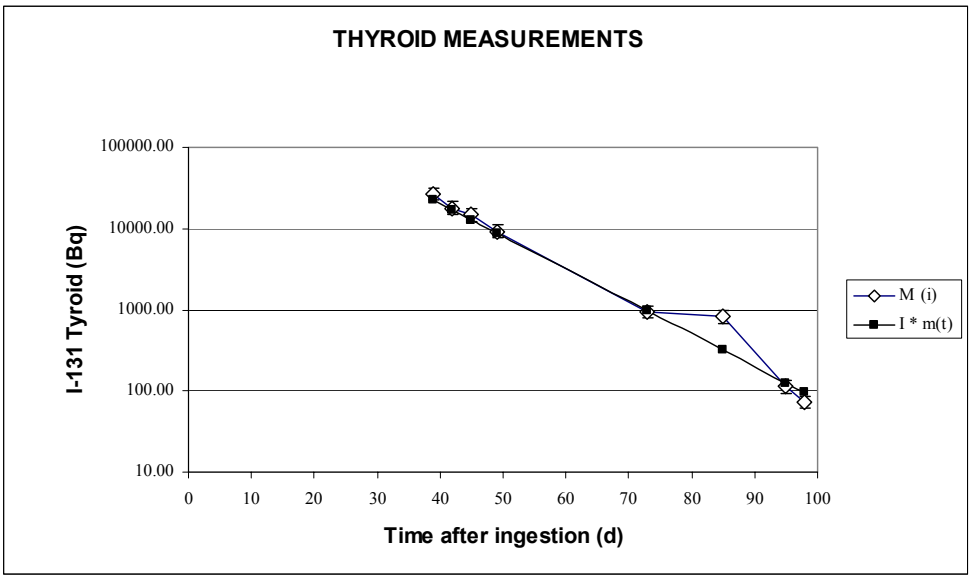

Fig. 1 – All I-131 Thyroid data measurements.

To a qualitative view, it is obvious that the measurement data M6 is an outlier and has to be eliminated from the subsequent evaluation.

Making also, a quantitative evaluation of every measurement data, considering it as it was the single data available, by calculating their errors there were obtained important results, mentioned in Table 1.

Table 1

The errors of singular intakes

Intake	**Intake value [Bq]**	**Error [%]**
I1	3397143	12.8
I2	3005726	1.5
I3	3314437	10.7
I4	2947515	–0.4
I5	2792234	–6
I6	7410326	*60*
I7	2572926	–15
I8	2181709	*–35.7*

It is confirmed, that the measurement data M6 is an outlier, because, comparing the range of the other seven singular intakes, its value exceed it too much, and the error is consistent. The IDEAS Guidelines propose one criterion for

checking if some data should be considered as outliers, namely, a measurement value is a possible outlier if it is more than a factor of SF^3 away from the trend of the other data. Applying this criterion is resulting that the measured value of 818 Bq is more than 183 Bq, the value of trend/SF^3, being confirmed, again, that the measurement data M6 is an outlier. Consequently, the data M6 was excluded from the data analysis. For a more precisely data analysis, it is noticed that also, the measurement data M8 generates an important intake underestimation.

The measurement data M8 is not an outlier, accordance to the IDEAS Guidelines.

Its contribution on the intake estimation was evaluated and declared on Table 2.

The monitoring data, they were processed for intake and effective dose estimation in 3 steps:

– The first 3 data, considering that they were obtained all in an interval of 7 days;

– All the remained 7 monitoring data, considering that the high effective doses require more data for the evaluation;

– All the 6 monitoring data, excluding the M6 and M8 monitoring.

The results obtained are presented in Table 2.

Table 2

Estimated Intake and committed effective doses, *E*(50) for two selections of monitoring data

Number of processed data	**Estimated Intake (Bq)**	**Real Intake (Bq)**	**Error (%) (absolute value)**	***E*(50) (mSv)**
First 3	3234628	2960000	9.3	71.16
7 (without M6)	2859570	2960000	3.4	62.91
6 (without M6 and M8)	2991470	2960000	1	65.81

To qualify the fit of the measurement data, it was performed the evaluation of the observed chi-square, with the formula:

$$\chi_0^2(I) = \sum_{i=1}^{n} \left(\frac{\ln(M_i) - \ln[I \times m(t_i)]}{\ln(\mathrm{SF}_i)} \right)^2 .$$

The values of 1.16 for $\chi_0^2(I)$ and of 0.88 > 0.05 for P-value certified us to consider that, there is a good fit of data, as could be seen in Fig. 2. There were considered all the 7 measurement data, without data M6.

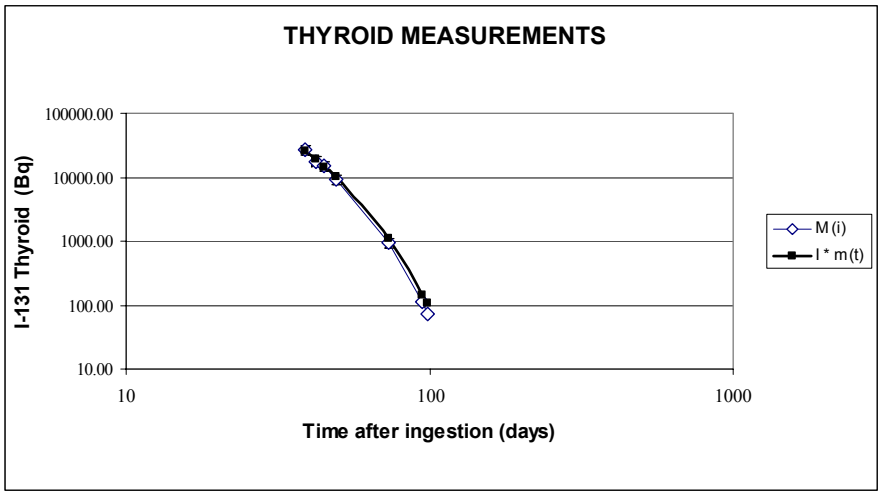

Fig. 2 – Selected I-131 thyroid data measurements.

4. CONCLUSIONS

The results obtained showed a good compliance of the measurements data with the model for iodine from ICRP78, fact that emphasizes the good quality of processed monitoring data. Moreover, a greater number of good monitoring data reduces the error of intake estimation. This gives us the certitude that the implemented method for the acute intake by ingestion and dose estimation, in WBML, is reliable and valid.

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