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Calibration of a whole body counter system for the dose assessment of occupationally exposed workers in Greece

Antonios Nikolakis-Plytzanopoulos [1,2], Konstantina Papadopoulou [1,2],
Nikolaos Salpadimos [1], Maria Kolovou [1], Konstantinos Karfopoulos† [1],
Constantinos Potiriadis [1]

[1]Environmental Radioactivity Monitoring Unit, Greek Atomic Energy Commission (EEAE)

[2]Department of Medicine, National and Kapodistrian University of Athens, Athens, Greece

1. Background-Aim

The Greek Atomic Energy Commission (EEAE) is the national regulatory authority competent for the control, regulation, and supervision in radiation related practices. To this end, occupational dosimetry practices are performed to investigate whether the established dose limits are exceeded. A widely accepted method for dose estimates due to internal contamination is a Whole Body Counter (WBC) setup.

This study aims to:

- calibrate a WBC system experimentally and virtually (by Monte Carlo - MC)
- extract the Minimum Detectable Activity (MDA) of the WBC setup
- perform dose assessment calculations due to inhalation of 131-I on occupationally exposed workers in Nuclear Medicine departments of Attica.

2. Materials & Methods – Calibration

This study utilizes an Accuscan WBC system, equipped with a HPGe detector manufactured by Canberra.

- The calibration procedure is supported by the RMC-II calibration phantom (fig. 1).

- The WBC system is modeled in the MC code PENELOPE and the system is calibrated virtually (fig. 2).

- The Minimum Detectable Activity (MDA) is calculated for a variety of radionuclides via the Curie formula:

$$MDA\ [Bq] = \frac{3 + 3.29\sqrt{N_{Bq}\frac{t_{aq}}{t_{Bg}}\left(1 + \frac{t_{aq}}{t_{Bg}}\right)}}{t_{aq} \cdot Eff \cdot yield}$$

Fig. 1: The WBC setup

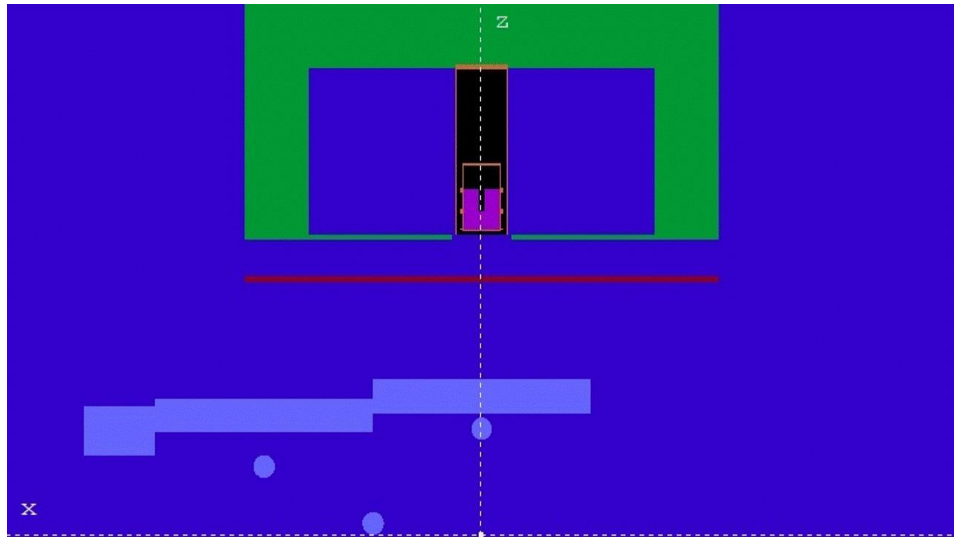

Fig. 2: The WBC model in PENELOPE

2. Materials & Methods – Internal Dosimetry

Dose assessment calculations due to inhalation of 131-I are performed for 10 workers in Nuclear Medicine departments of Attica:

- 7 medical physicists
- 3 medical technologists

The IMBA (ICRP 60/68) and CADORmed dosimetry software packages were utilized for calculating the effective dose, assuming:

1. a light worker (ICRP):
   - $2.5h$ sitting with a breathing rate of $0.54m^3/h$
   - $5.5h$ light exercise with a breathing rate of $1.5m^3/h$
2. all-year continuous exposure.

3. Results – Calibration

- Good convergence between experimental and MC efficiency → 6% mean rel. Bias (fig.3)
- Significant deviation in lower energies (59.54 keV) → 15-30% rel. Bias (fig.3)

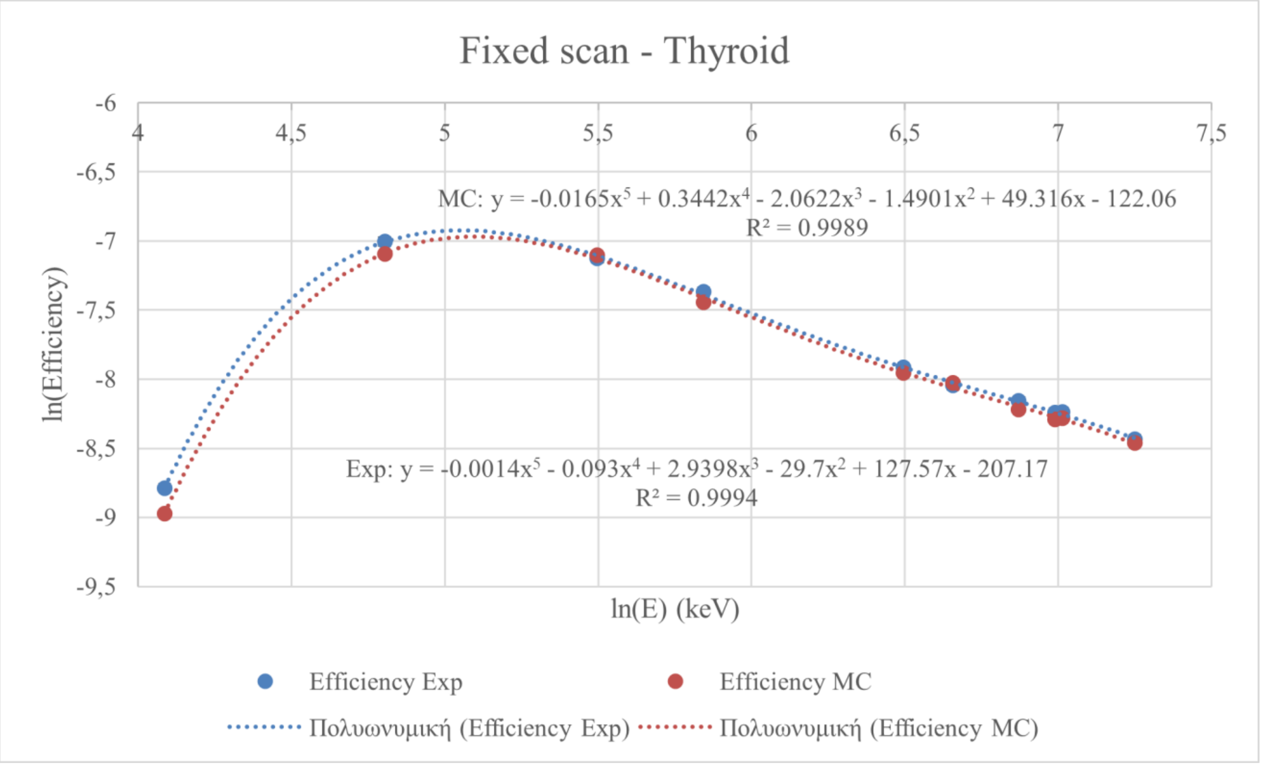

Fig.3: Efficiency curves for fixed scan and the isotopes in Thyroid position: with red the MC efficiency curve, with blue the Experimental efficiency curve. A good agreement between the curves is reached for energies over 100keV

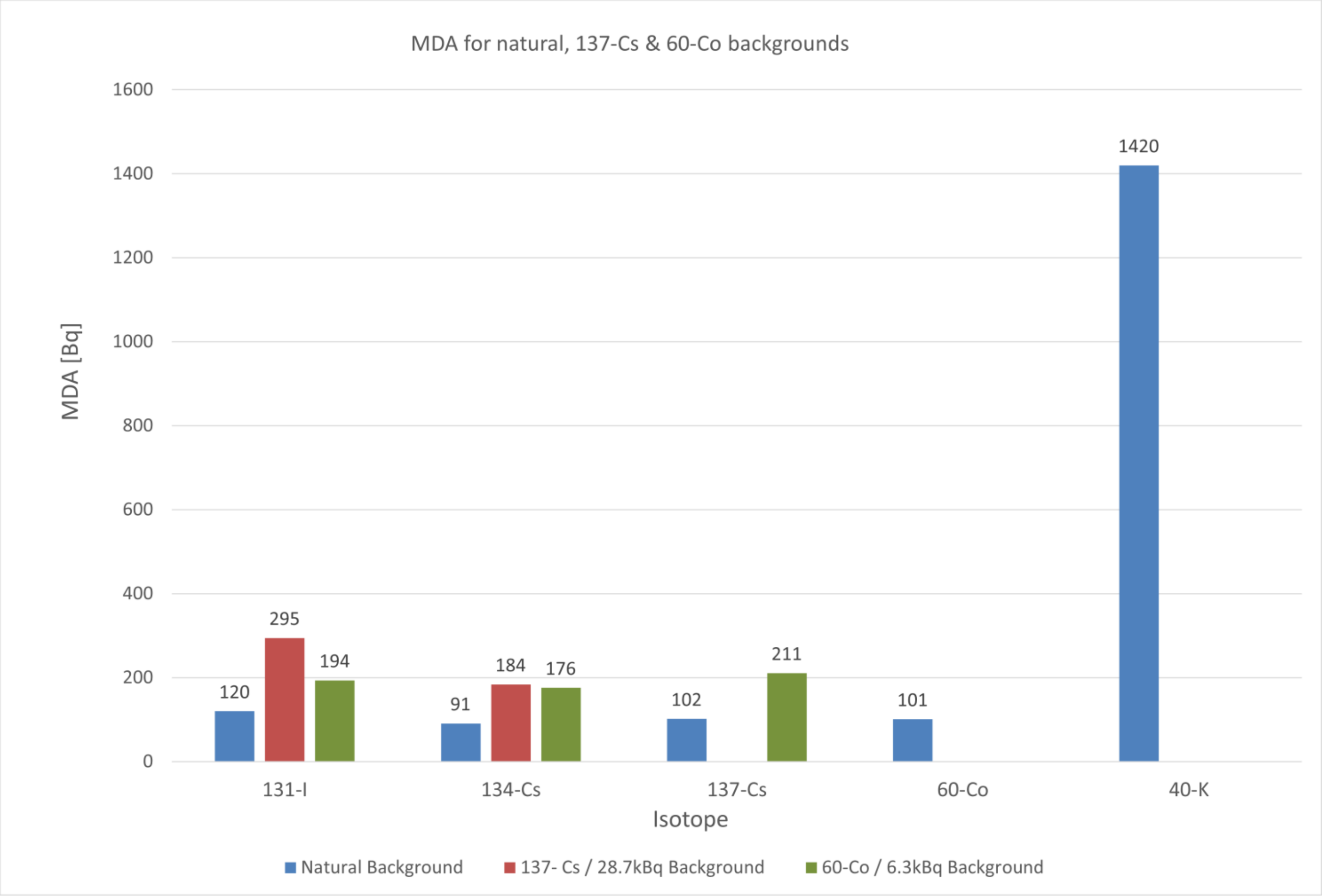

Fig.4: MDA for multiple backgrounds and isotopes

- MDAs were calculated under different background conditions (natural, 137-Cs, 60-Co) using the Curie formula for the isotopes: 131-I, 134-Cs, 137-Cs, 60-Co, 40-K (fig.4).

3. Results – Internal Dosimetry

- No 131-I peak is observed in 9 out of 10 workers' spectrums → it is assumed as a worst-case scenario that the activity of 131-I inhaled is just below the MDA limit of $120Bq$

- The activity-time curve of 131-I in the human body takes form in fig.5. Since no significant absence from work was noted from any worker, it is safe to assume that the workers are being measured in the plateau region

- For a plateau of $MDA = 120Bq$ in the activity-time curve (fig.5), each worker inhales $57.5\ Bq/d$ and the 131-I concentration in air reaches $6\ Bq/m^3$.

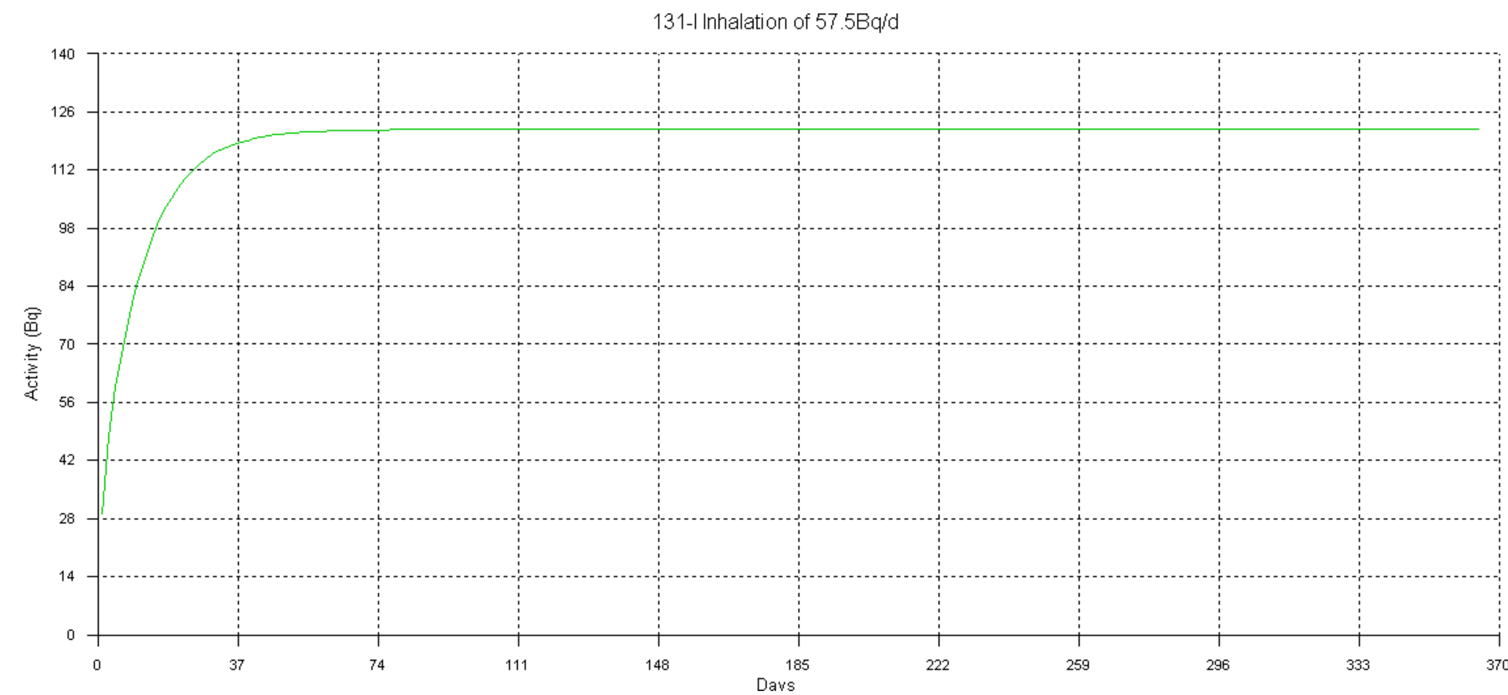

Fig.5: Activity-time curve of a light worker (ICRP), assuming inhalation of 131-I of 57.5 Bq/d , every day for 365 d/y. A plateau of 120Bq is reached within the first month.

↓

This scenario leads to an effective dose of 0.22mSv (IMBA)

3. Results – Internal Dosimetry

- In 1 out of 10 spectrums the 131-I peak is observed. After questioning the individual it was apparent that 131-I had contacted his skin through a tear in his/her glove, the day before the measurement.

- The total net area of the peak was determined to be N=94 counts and the activity of the isotope is calculated, by the formula : $A = \frac{N}{eff \cdot t_{aq} \cdot yield} = 613 \pm 63\ Bq$

- 2 exposure scenarios were assumed:
  1. Inhalation
  2. Direct injection to the blood flow

		IMBA		CADORmed	
Exposure	AMAD (μm)	A_0 (kBq)	Eff. Dose (mSv)	A_0 (kBq)	Eff. Dose (mSv)
Inhalation	1	3.50	0.026	3.40	0.025
	5	2.15	0.023	2.03	0.022
Injection	-	1.86	0.040	1.91	0.032

4. Conclusions

- The virtual calibration of a WBC system via MC simulation is a viable method. The significant deviations of the MC model in lower energies (below 100keV) are not of any concern because Whole Body Counting is viable for energies above 100keV due to strong attenuation.

- For the workers that inhaled quantities of 131-I below the MDA limit, the worst-case scenario effective dose of 0.22mSv is below the annual limit of 20mSv.

- The contamination case, in which the 131-I peak was present, leads to a worst-case scenario dose of 0.04mSv that is negligible compared to the annual limit of 20mSv.

- In any case, the estimated effective doses do not exceed the annual limit of 20mSv, leading to the conclusion that radiation protection practices are properly followed.

5. References

- European Council Directive 2013/59/Euratom on basic safety standards for protection against the dangers arising from exposure to ionising radiation and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. OJ of the EU. L13; 57: 1–73 (2014).

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