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Large scale individual thyroid monitoring following nuclear accidents by means of non-spectrometric devices

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INTRODUCTION

In order to properly respond to an emergency caused by an accident or a deliberate terrorist attack in a nuclear power plant with spread of radionuclides in atmosphere, we propose a procedure to perform on field a large scale individual thyroid monitoring of internal contamination due to ^{131}I by means of non-spectrometric equipment. After an acute inhalation, ^{131}I typically concentrates one day later almost exclusively in the thyroid glands. Therefore, for thyroid measurements the use of rate meters calibrated in ambient dose rate equivalent H*(10) (reading values in μSv/h) offers a suitable alternative to spectrometric technique, being cheaper, readily portable and simple to operate. Specific attention is paid on individual monitoring of five and ten years old children, being the sensitive population group with an increased risk of developing thyroid cancer.

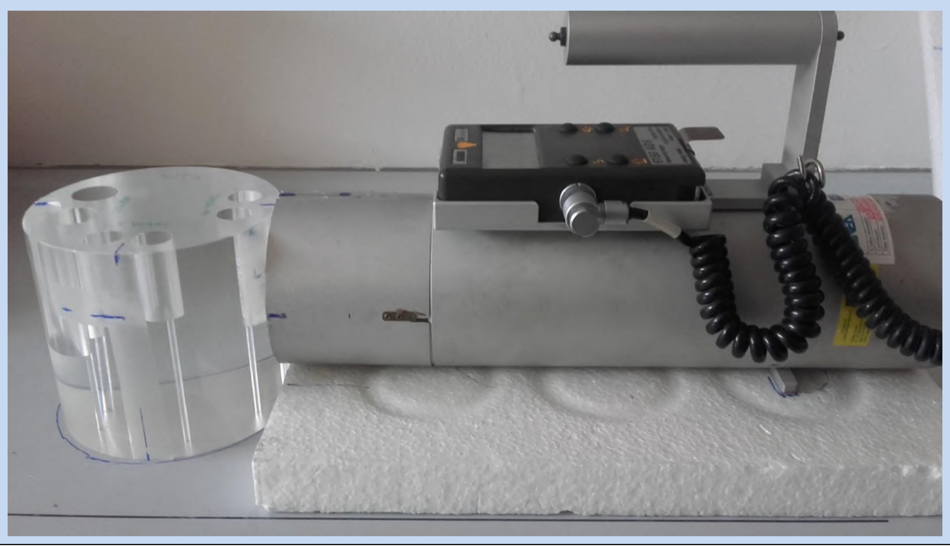
MATERIALS & METHODS

Automess 6150 AD-b

- Dose rate meter (2.5 kg)
- Cylindrical 3" diameter by 3" plastic scintillator
- Dose rate range: 1 nSv/h to 99.9 μSv/h
- Linearity of dose rate measurement: deviation typically ±5% for energy > 200 keV
- Operation life with internal battery: 120 h
- Usually employed for environmental surveys

Rate meter thyroid calibration. The Calibration Factors (CF) - expressed in terms of kBq/(μSv/h) – were evaluated by means of an age-dependent neck phantom, proposed in the project *Child and Adult Thyroid Monitoring After Reactor Accident (CAThyMARA).* It consists of a plexiglass cylinder representing the neck (13[Φ] × 12[L] cm^2), with three pairs of holes for inserting the vials, representing the thyroid glands of different ages:

- 2 vials (1.6 ml each) for a 5 y/o thyroid
- 2 vials (3.75 ml each) for a 10 y/o thyroid
- 2 vials (9.5 ml each) for an adult thyroid
- Vials spiked with ^{131}I liquid sources (nominal activities for each age group equal to 2 kBq, 6 kBq and 15 kBq)
- ^{131}I vials calibrated by means of a ^{133}Ba (356 keV) certified liquid source and a N-type crystal HPGe gamma-ray spectrometer (44% relative efficiency and 2 keV energy resolution at 1332 keV)
- Distance rate meter-neck: at contact
- No collimation



RESULTS

Device performances were evaluated by measuring mock-iodine sources (mixture of ^{133}Ba and ^{137}Cs sources in combination with a 1 mm Ag filter) provided in the *CAThyMARA* intercomparison (deviation calculated according to ISO 13528). The employed rate meter shows a remarkable accuracy (uncertainties with coverage factor k = 1) in quantification of equivalent ^{131}I in thyroids (deviation ≤ 5%).

CATHyMARA Intercomparison				
Age	CF (kBq/[μSv/h])	Mock-iodine sources (Bq)	Provided results (Bq)	Deviation (%)
5 y/o	50,8 ± 3,2	2483 ± 124	2359 ± 307	-5,0
10 y/o	55,4 ± 3,9	5642 ± 282	5638 ± 451	-0,1
adult	70,6 ± 5,4	14063 ± 703	13549 ± 881	-3,7

Detection Limit (DL) values in Bq were evaluated on 60 s acquisition time for different volunteers, in particular 51 measurements of adult thyroids and 21 measurements of 10 y/o thyroids, by using ISO 11929 methodology. "DL committed equivalent dose to thyroid" (H_T) values in mSv (i.e. the equivalent dose corresponding to an *in vivo* amount equal to a DL value) were evaluated by means of the MONDAL3 software with the hypothesis of an acute inhalation intake occurred 3 days before the measurement.

DL – dose performances						
Age Group	Weight (kg)	Background (nSv/h)	Thyroid dose rate (nSv/h)	DLs (Bq)	^{131}I Intake (kBq)	H_T (mSv)
10 y/o (Male)	48 ± 12	212 ± 3	185 ± 3	887	11	4,1
10 y/o (Female)	38 ± 6	212 ± 3	189 ± 3	889	11	4,1
Adult (Male)	81 ± 11	152 ± 4	114 ± 4	1226	16	2,4
Adult (Female)	60 ± 9	152 ± 4	122 ± 5	1655	22	3,3

Examples of geometry of data acquisition with dose rate meters

The mean thyroid gamma radiations result to be less than the background gamma radiation (the human body works as a shielding).

The employed rate meter shows DL values resulting in a maximum H_T equal to 4.1 mSv (related to 10 y/o children).

Supposing most likely same dose rate deviation (k = 1) of the thyroid gamma radiation for 5 y/o children as for 10 y/o children, a H_T value equal to 8.0 mSv for 5 y/o children is obtained.

CONCLUSIONS

The adopted rate meter guarantees an assessment of committed equivalent doses to thyroid greater than 10 mSv due to ^{131}I inhalation if monitoring is carried out within three days after intake. The projected equivalent thyroid dose reference level - recommended by World Health Organization for implementing iodine thyroid blocking – is 50 mSv for the first seven days since the onset of exposure, therefore the **observed performance level makes the rate meter a very useful tool to be used for fast thyroid monitoring in nuclear emergencies**.

Needless to say, priority has to be given to children monitoring, being the individuals at higher risk of developing radiation-induced thyroid cancer compared to adults.

The procedure here proposed cannot be exhaustive; this kind of measurements has to be carried out in conjunction with whole-body measurements in order to fully assess a committed effective dose due to all the gamma emitters involved in a nuclear accident. However we think that, in situations of high emotional tension, it is very important to identify in 60 s acquisition time thyroids which need medical therapies by just using simple devices like the non-spectrometric ones. In these scenarios the rapidity plays a key role, since the reasonable period of administration of stable iodine is less than 24 hours following the exposure.

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