Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Method optimization approach applied to the determination of Am-241 in urine in emergency situations

D. Gorietti, F. Modestia, D. Pirullo, P. Battisti

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Speaker: Daniela Gorietti, PhD

ENEA Researcher – Radiation Protection Insitute
Laboratory of Radioactivity Measurement and Monitoring (IRP-MIR)

European Radiation Dosimetry Group e.V.

GUIDANCE REPORT ON SCREENING AND RAPID METHODS FOR IN VITRO EMERGENCY BIOASSAY

Authors: I. Sierra, F. Verrezen, D. Arginelli, P. Battisti, D. Blazquez, C. Guichet, C. Navas, D. Ullmann, M. Bruggeman, A. Rojas, M.A. López, D. Broggio

https://eurados.sckcen.be/sites/eurados/files/uploads/Report-Publications/Reports/2025/EURADOS%20Report%202025-03.pdf

Highlights

- Project measurement techniques suitable for the potential internal contamination monitoring in emergency situations, based on the concept of “minimum detectable dose”
- Identify in advance the operating parameters to play with to simplify the techniques used in routine monitoring to adapt them to mass monitoring
- Identify in advance the time interval useful for sample collection
- Application of this approach to the determination of ^{241}Am in small urine samples by alpha spectrometry

Daniela Gorietti – daniela.gorietti@enea.it

Radiological emergency

Accidental or intentional events involving the dispersion of significant quantities of radioactive materials into the environment

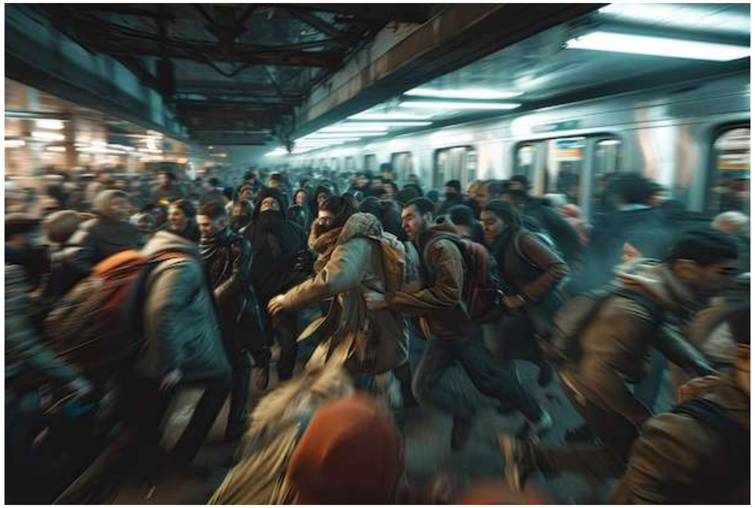
Environmental contamination

General population exposure

Long term stochastic effects evaluation

The evaluation of the committed effective dose on the population could be performed by different approach :

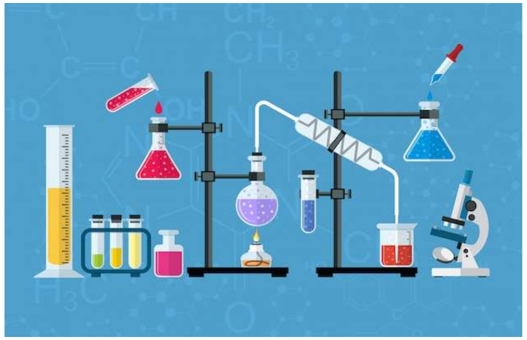
- Dose estimation from data obtained by environmental measurements
- Dose estimation using a statistical approach on the monitoring data resulting from a restricted number of participant considered representative of the hole population involved
- Extended individual monitoring

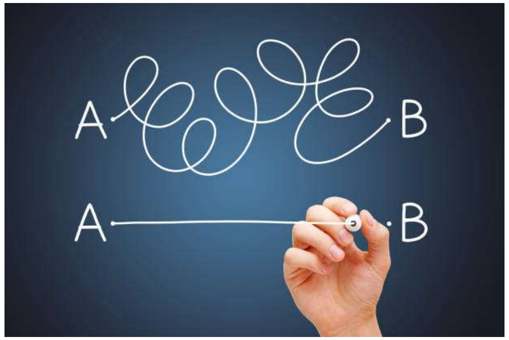


Extended individual monitoring requirements

1) Availability of a sample matrix easy to get and to manage

2) Carry out a large number of analyses in the shortest possible time



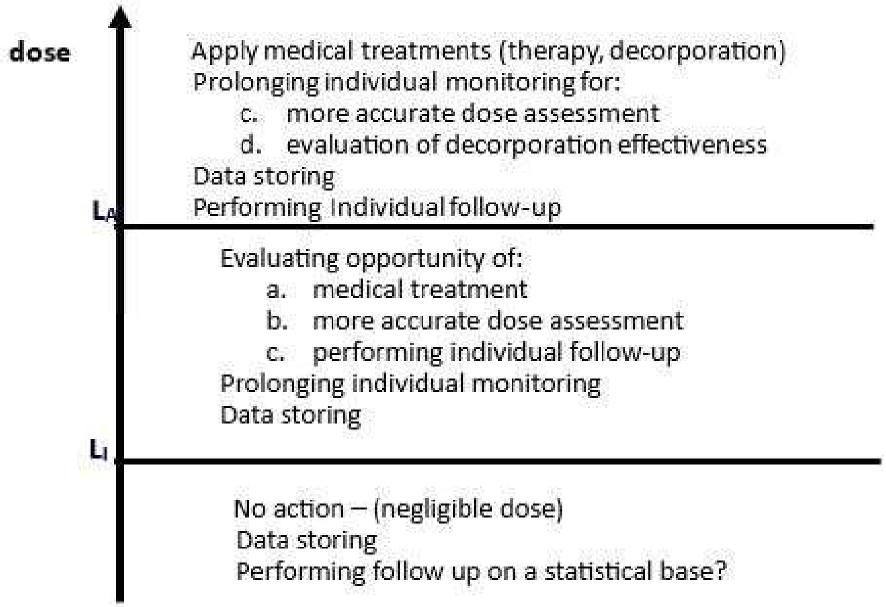


3) Results sufficiently reliable and easily interpretable

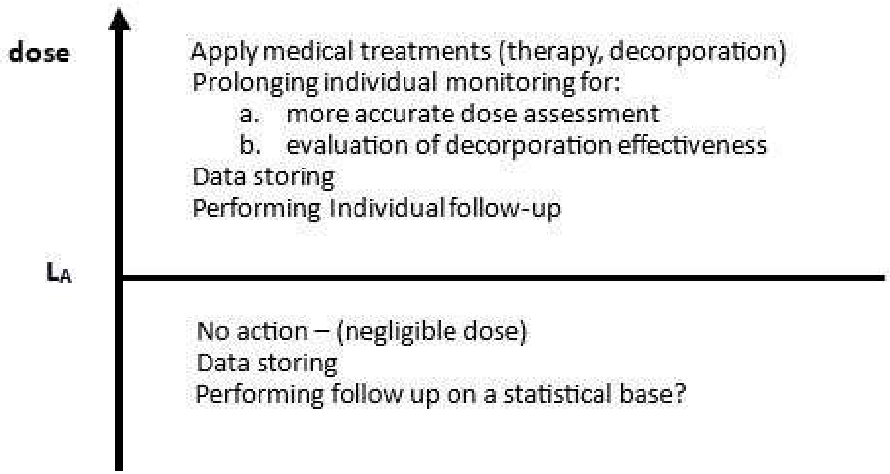
estimation of the dose deriving from the potential internal contamination

Evaluation of a mass screening outcome

TWO-LEVEL OPERATIONAL SCHEME



SINGLE LEVEL OPERATIONAL SCHEME



References:

ICRP, «Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situation,» ICRP Publication 109, 2009.

ICRP, «Radiological Protection of People and the Environment in the Event of a Large Nuclear Accident,» ICRP Publication 146, 2020

Evaluation of a mass screening outcome

Detection Limit, DL
(counts)

Reference Level, RL
(mSv)

SINGLE LEVEL OPERATIONAL SCHEME

dose

Apply medical treatments (therapy, decorporation)
Prolonging individual monitoring for:
  a. more accurate dose assessment
  b. evaluation of decorporation effectiveness
Data storing
Performing Individual follow-up

L_A

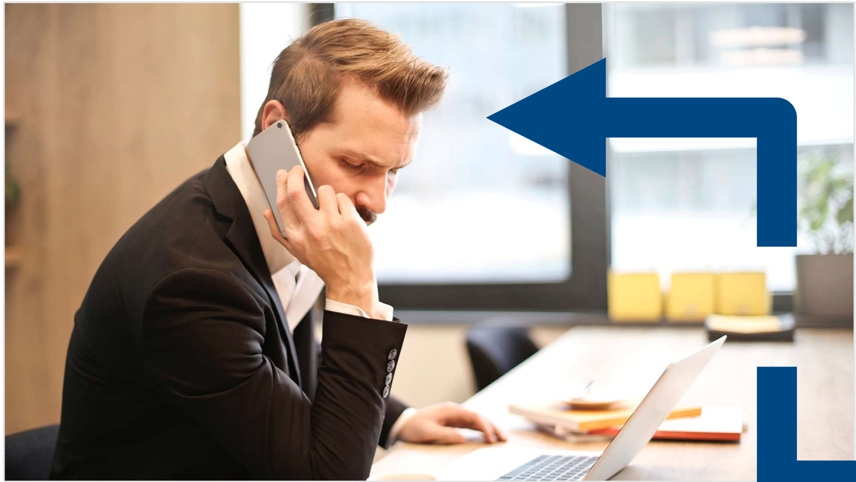
No action – (negligible dose)
Data storing
Performing follow up on a statistical base?

Evaluation of a mass screening outcome

Communication must be immediate and effective

RL, dose limit = mSv

DL, measuremet results = counts



Easy interpretation of the experimental results in terms of dose limit is surely desired

Criterion of applicability

RL conversion in terms of counts

Variable	Symbol	Formula	UOM	Notes
Intake	I(RL)	$\frac{RL}{e(50)}$	Bq	e(50): proper dose coefficient

Criterion of applicability

RL conversion in terms of counts

Variable	Symbol	Formula	UOM	Notes
Intake	I(RL)	$\frac{RL}{e(50)}$	Bq	e(50): proper dose coefficient
Activity normalized to 24 h	$A_{24h}(t)$	$I(\mathrm{RL}) \cdot m(t)$	Bq/d	m(t): proper excretion function t: elapsed time between the intake and the sample collection

Criterion of applicability

RL conversion in terms of counts

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Intake	I(RL)	$\frac{RL}{e(50)}$	Bq	e(50): proper dose coefficient
Activity normalized to 24 h	$A_{24h}(t)$	$I(\mathrm{RL}) \cdot m(t)$	Bq/d	m(t): proper excretion function t: elapsed time between the intake and the sample collection
Activity	$A_V(t)$	$A_{24h}(t) \cdot \frac{V}{1.6}$	Bq	V: sample volume analyzed (L) 1,6 L/d: daily urinary standard excretion (*)

References:

(*) ICRP, «Basic Anatomical and Physiological Data for Use in Radiological Protection. Reference Values,» ICRP Publication 89 Ann. ICRP 32 (3-4), 2002.

Criterion of applicability

RL conversion in terms of counts

Variable	Symbol	Formula	UOM	Notes
Intake	I(RL)	$\frac{RL}{e(50)}$	Bq	e(50): proper dose coefficient
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Activity	$A_V(t)$	$A_{24h}(t) \cdot \frac{V}{1.6}$	Bq	V: sample volume analyzed (L) 1,6 L/d: daily urinary standard excretion (*)
Counts	$C_{S,T_m}(t)$	$A_V(t) \cdot T_m \cdot Y \cdot \varepsilon \cdot \rho$	-	T_m: counting time (s) Y: emission yield ε: efficiency ρ: chemical yield

Criterion of applicability

RL conversion in terms of counts

$$C_{S,T_m}(t) = I(\mathrm{RL}) \cdot m(t) \cdot \frac{V}{1.6} \cdot T_m \cdot Y \cdot \varepsilon \cdot \rho \geq \mathrm{DL}$$

Notes:

DL = Detection Limit of the measurement technique, calculated according to ISO 11929-1

Criterion of applicability: DL ≤ $C_{S,T_m}(t)$

How to project the operating procedures so that the measurement technique is suitable for the specific monitoring

$$C_{S,T_m}(t) = I(RL)\, m(t) \cdot \frac{V}{1.6} \cdot T_m \cdot Y \cdot \varepsilon \cdot \rho \geq DL$$

Optimized parameters

- Increase the RL is a simple and fast choice but it must be evaluated very carefully since it could have serious health and politic repercussions in case of underestimation of risks and consequences

RL = 10 mSv

- Increasing the volume analyzed affect the speed and the defeaturing of the procedure, especially in terms of productivity.

V = 50 ml

- Increasing the T_m clearly grow up also the registered counts but, to the same extent, the response time raises too

T_m = 80.000 s

Analytical procedure

Daniela Gorietti – daniela.gorietti@enea.it

Determination of ^{241}Am in 50 ml urine sample

50 ml urine

↓ Yield tracer added: ^{243}Am

Hot acid mineralization

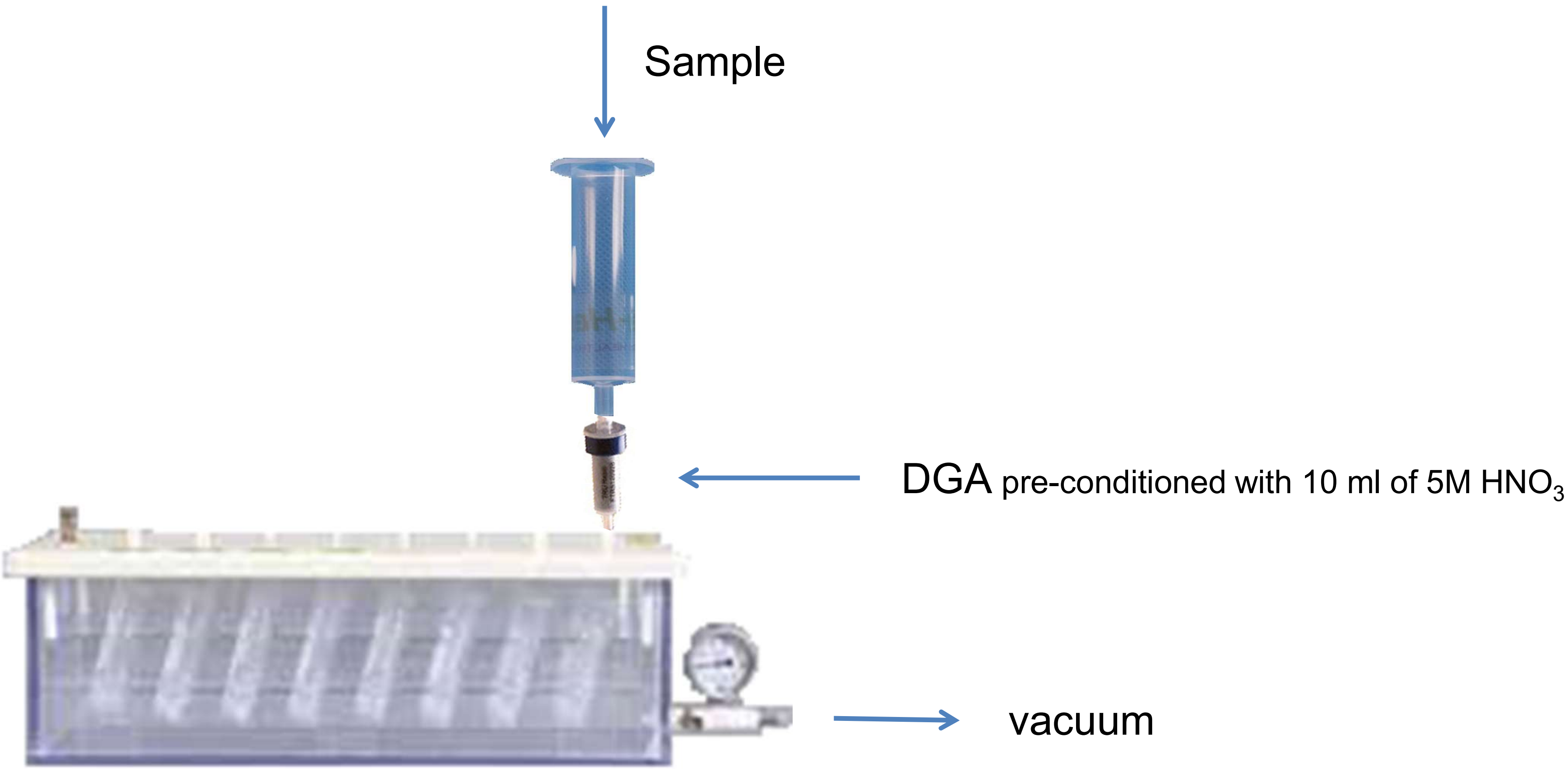
10 ml 69% HNO_3
5 ml 30% H_2O_2

↓ Evaporated and resumed several times with
4 ml 69% HNO_3 + 2 ml 30% H_2O_2

Dissolved in 10 ml of 5M HNO_3 – 1M $Al(NO_3)_3$

Determination of ^{241}Am in 50 ml urine sample

Am separation by solid extraction chromatography (SPE)

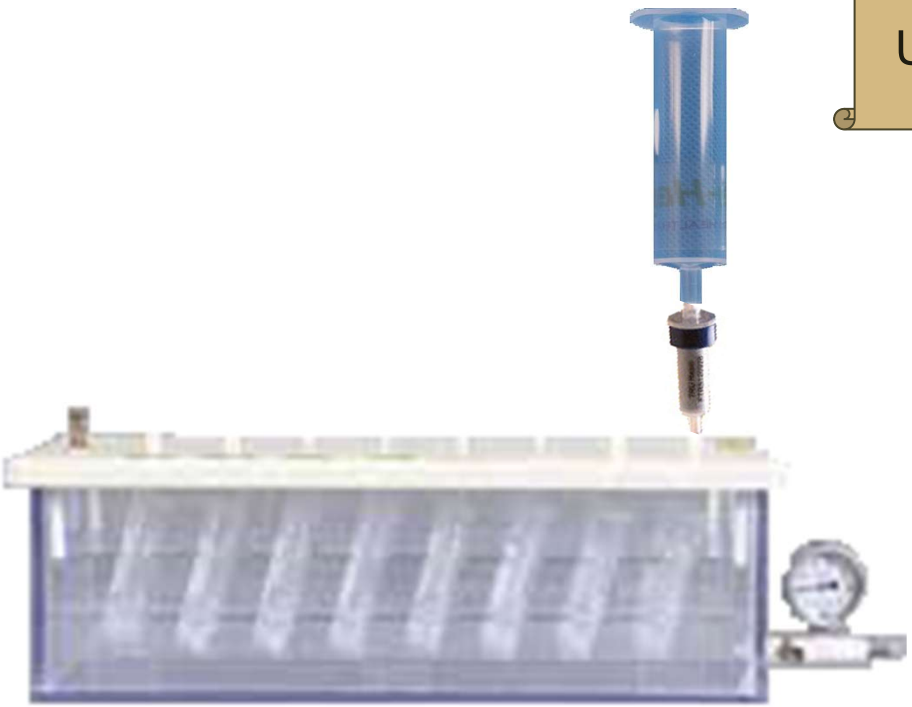


Determination of ^{241}Am in 50 ml urine sample

Am separation by solid extraction chromatography (SPE)

5+5 ml 5M HNO_3
20 ml 0,1M HNO_3

U, Th



vacuum

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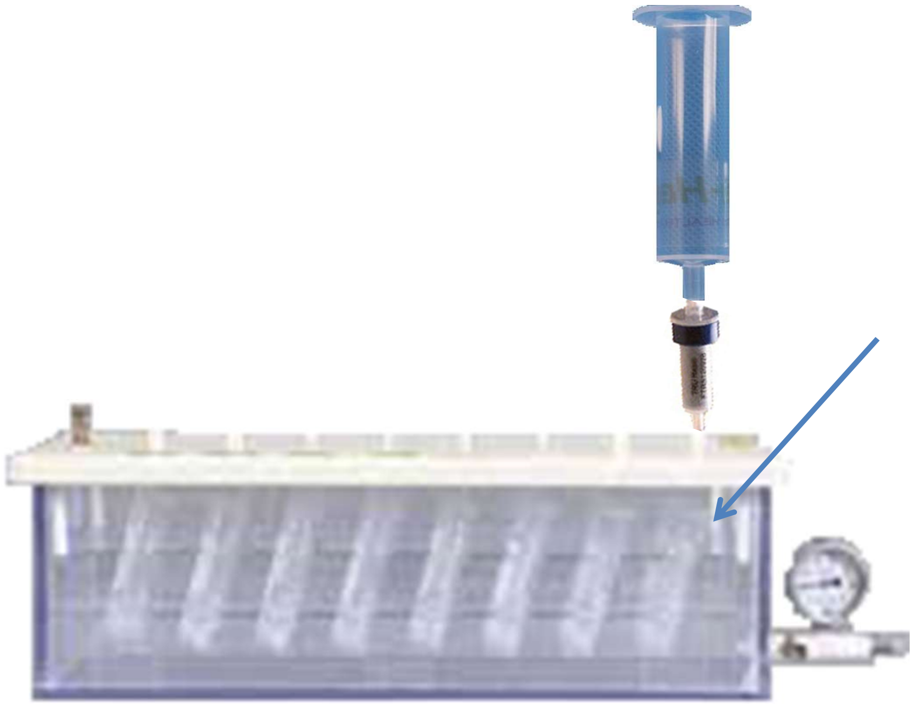
Determination of ^{241}Am in 50 ml urine sample

Am separation by solid extraction chromatography (SPE)

Eluition with 20 ml 0,5M HCl



EDP

Counting time T_m = 80.000 s

vacuum

Results and discussion

Results and discussion

The chemical yield obtained are generally very high (> 90%) and with an adequate supplies of experienced staff, this method allows a single, properly equipped working line, to complete 8 measurements in about 30-35 hours

DL (i)	MDA (ii)	MDA_{24h} (iii)
(cp)	(Bq/L)	(Bq/d)
7,5	6,3 E-03	1,0 E-02

Notes:

(i) Calculated according to ISO 11929-4 - Determination of the characteristic limits (decision threshold,, detection limit and limits of the coverage interval) for measurements of ionizing radiation - Fundamentals and application – Part 4: Guidelines to applications, 2022

(ii) Calculated according to ISO 28218 - Radiation Protection - Performance criteria for radiobioassay, 2010.

(iii) Calculated as: $MDA_{24h} = MDA \cdot 1,6$

Applicability criterion: DL = 7,5 ≤ $C_{S,T_m}(t)$

The tecnique here proposed is suitable for the monitoring of Am isotopes in emergency situation, if:

$$DL \leq C_{S,T_m}(t) = I(RL) \cdot m(t) \cdot \frac{V}{1.6} \cdot T_m \cdot Y \cdot \varepsilon \cdot \rho$$

$$\frac{RL}{e(50)}$$

Optimized parameters

- **DL = 7,5**
- **ε = 0,33**
- **ρ = 0,90**
- **RL = 10 mSv**
- **V = 50 ml**
- **T_m = 80.000 s**

Note:

e(50): proper dose coefficient

m(t): proper excretion function

Available on specific database, for example OIR Data Viewer, https://icrp.org/page.asp?id=505 (Occupational Intake of Radionuclides Viewer Desktop App)

Applicability criterion: DL = 7,5 ≤ $C_{S,T_m}(t)$

$C_{S,T_m}(t)$ values obtained for ^{241}Am applying the proposed monitoring procedure to urine samples collected in the first seven days following an intake corresponding to a dose equal to the RL

$C_{S,T_m}(t)$ (counts) – Intake ^{241}Am									
t	**Inhalation of aerosol**								**Ingestion**
(days from intake)	**Type F**		**Type M**		**Type S**		**Nitrate**		**All compounds**
(d)	**1 μm**	**5 μm**	**1 μm**	**5 μm**	**1 μm**	**5 μm**	**1 μm**	**5 μm**	**Soluble/Insoluble**
1	860	878	244	251	6	6	603	589	3780
2	782	743	228	213	5	5	557	498	579
3	586	540	180	167	4	4	427	375	277
4	430	392	138	121	3	3	316	276	164
5	317	284	106	93	2	2	232	199	116
6	234	209	80	74	2	2	176	153	92
7	176	155	64	59	1	1	135	115	79

Applicability criterion: DL = 7,5 ≤ $C_{S,T_m}(t)$

$$C_{S,T_m}(t) = I(\mathrm{LR}) \; m(t) \cdot \frac{V}{1.6} \cdot T_m \cdot Y \cdot \varepsilon \cdot \rho$$

$C_{S,T_m}(t)$ (counts) – Intake ^{241}Am									
t	**Inhalation of aerosol**								**Ingestion**
(days from intake)	**Type F**		**Type M**		**Type S**		**Nitrate**		**All compounds**
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3	586	540	180	167	4	4	427	375	277
4	430	392	138	121	3	3	316	276	164
5	317	284	106	93	2	2	232	199	116
6	234	209	80	74	2	2	176	153	92
7	176	155	64	59	1	1	135	115	79

Minimum Detectable Dose MDD(t)

Dynamic applicability criterion

The measurement technique can be considered suitable for the specific monitoring
as long as

$$\mathrm{DL} \leq C_{S,T_m}(t) \longrightarrow MDD(t) < \mathrm{RL}$$

In terms of counts — In terms of dose

MDD(t)

Committed effective dose corresponding to an activity measured in the sample (collected at a time t from the intake) equal to the minimum detectable activity (MDA) of the measurement technique adopted for the screening

Applicability criterion: MDD(t) ≤ RL and t ≥ 5 d

Technique can be considered suitable for the specific monitoring **as long as**

$$LD \leq C_{S,T_m}(t) = I(\mathrm{LR}) \cdot m(t) \cdot \frac{V}{1.6} \cdot T_m \cdot Y \cdot \varepsilon \cdot \rho$$

Example: ^{241}Am inhalation of type F aerosol (AMAD = 1 µm)

t	m(t)	$A_{24h}(t) = MDA_{24h}$	Intake	E50 = MDD(t)	Ratio
(d)	AMAD = 1 µm	(Bq/d)	(Bq)	(mSv)	MDD(t)/LR
1	$2.2\ 10^{-3}$	$1.0\ 10^{-2}$	$4.5\ 10^{0}$	$8{,}6\ 10^{-2}$	0.9%
2	$2.0\ 10^{-3}$	$1.0\ 10^{-2}$	$5.0\ 10^{0}$	$9{,}5\ 10^{-2}$	1.0%
3	$1.5\ 10^{-3}$	$1.0\ 10^{-2}$	$6.7\ 10^{0}$	$1{,}3\ 10^{-1}$	1.3%
4	$1.1\ 10^{-3}$	$1.0\ 10^{-2}$	$9.1\ 10^{0}$	$1{,}7\ 10^{-1}$	1.7%
5	$8.1\ 10^{-4}$	$1.0\ 10^{-2}$	$1.2\ 10^{1}$	$2{,}3\ 10^{-1}$	2.3%
6	$6.0\ 10^{-4}$	$1.0\ 10^{-2}$	$1.7\ 10^{1}$	$3{,}2\ 10^{-1}$	3.2%
7	$4.5\ 10^{-4}$	$1.0\ 10^{-2}$	$2.2\ 10^{1}$	$4{,}2\ 10^{-1}$	4.2%
40	$1.90\ 10^{-5}$	$1.0\ 10^{-2}$	$5.3\ 10^{2}$	$1.0\ 10^{1}$	100%

Notes:

Intake calculated as $\frac{MDA_{24h}}{m(t)}$

Applicability criterion: MDD(t) ≤ RL and t ≥ 5 d

^{241}Am inhalation of type F aerosol (AMAD = 5 μm)

t	m(t)	$A_{24h}(t) = MDA_{24h}$	Intake	E50 = MDD(t)	Ratio
(d)	AMAD = 5 μm	(Bq/d)	(Bq)	(mSv)	MDD(t)/LR
1	$1.3\ 10^{-3}$	$1.0\ 10^{-2}$	$7.7\ 10^{0}$	$8,5\ 10^{-2}$	0.8%
2	$1.1\ 10^{-3}$	$1.0\ 10^{-2}$	$9.1\ 10^{0}$	$1,0\ 10^{-1}$	1.0%
3	$8.0\ 10^{-4}$	$1.0\ 10^{-2}$	$1,2\ 10^{1}$	$1,4\ 10^{-1}$	1.4%
4	$5.8\ 10^{-4}$	$1.0\ 10^{-2}$	$1,7\ 10^{1}$	$1,9\ 10^{-1}$	1.9%
5	$4.2\ 10^{-4}$	$1.0\ 10^{-2}$	$2,4\ 10^{1}$	$2,6\ 10^{-1}$	2.6%
6	$3.1\ 10^{-4}$	$1.0\ 10^{-2}$	$3,2\ 10^{1}$	$3,5\ 10^{-1}$	3.5%
7	$2.3\ 10^{-4}$	$1.0\ 10^{-2}$	$4,3\ 10^{1}$	$4,8\ 10^{-1}$	4.8%
37	$1.1\ 10^{-5}$	$1.0\ 10^{-2}$	$9,1\ 10^{2}$	$1,0\ 10^{1}$	100%

^{241}Am inhalation of type M aerosol (AMAD = 1 μm)

t	m(t)	$A_{24h}(t) = MDA_{24h}$	Intake	E50 = MDD(t)	Ratio
(d)	AMAD = 1 μm	(Bq/d)	(Bq)	(mSv)	MDD(t)/LR
1	$4.6\ 10^{-4}$	$1.0\ 10^{-2}$	$2,2\ 10^{1}$	$3,0\ 10^{-1}$	3.0%
2	$4.3\ 10^{-4}$	$1.0\ 10^{-2}$	$2,3\ 10^{1}$	$3,3\ 10^{-1}$	3.3%
3	$3.4\ 10^{-4}$	$1.0\ 10^{-2}$	$2,9\ 10^{1}$	$4,1\ 10^{-1}$	4.1%
4	$2.6\ 10^{-4}$	$1.0\ 10^{-2}$	$3,9\ 10^{1}$	$5,4\ 10^{-1}$	5.4%
5	$2.0\ 10^{-4}$	$1.0\ 10^{-2}$	$5,0\ 10^{1}$	$7,0\ 10^{-1}$	7.0%
6	$1.5\ 10^{-4}$	$1.0\ 10^{-2}$	$6,7\ 10^{1}$	$9,3\ 10^{-1}$	9.3%
7	$1.2\ 10^{-4}$	$1.0\ 10^{-2}$	$8,3\ 10^{1}$	$1,2\ 10^{0}$	12%
250	$1.4\ 10^{-5}$	$1.0\ 10^{-2}$	$7,1\ 10^{2}$	$1,0\ 10^{1}$	100%

^{241}Am inhalation of nitrate aerosol (AMAD = 1 μm)

t	m(t)	$A_{24h}(t) = MDA_{24h}$	Intake	E50 = MDD(t)	Ratio
(d)	AMAD = 1 μm	(Bq/d)	(Bq)	(mSv)	MDD(t)/LR
1	$1.3\ 10^{-3}$	$1.0\ 10^{-2}$	$7.7\ 10^{0}$	$1.2\ 10^{-1}$	1.2%
2	$1.2\ 10^{-3}$	$1.0\ 10^{-2}$	$8.3\ 10^{0}$	$1.3\ 10^{-1}$	1.3%
3	$9.2\ 10^{-4}$	$1.0\ 10^{-2}$	$1.1\ 10^{1}$	$1.7\ 10^{-1}$	1.7%
4	$6.8\ 10^{-4}$	$1.0\ 10^{-2}$	$1.5\ 10^{1}$	$2.3\ 10^{-1}$	2.4%
5	$5.0\ 10^{-4}$	$1.0\ 10^{-2}$	$2.0\ 10^{1}$	$3.2\ 10^{-1}$	3.2%
6	$3.8\ 10^{-4}$	$1.0\ 10^{-2}$	$2.6\ 10^{1}$	$4.2\ 10^{-1}$	4.2%
7	$2.9\ 10^{-4}$	$1.0\ 10^{-2}$	$3.4\ 10^{1}$	$5.5\ 10^{-1}$	5.5%
150	$1.6\ 10^{-5}$	$1.0\ 10^{-2}$	$6.2\ 10^{2}$	$1.0\ 10^{1}$	100%

^{241}Am inhalation of type M aerosol (AMAD = 5 μm)

t	m(t)	$A_{24h}(t) = MDA_{24h}$	Intake	E50 = MDD(t)	Ratio
(d)	AMAD = 5 μm	(Bq/d)	(Bq)	(mSv)	MDD(t)/LR
1	$2.7\ 10^{-4}$	$1.0\ 10^{-2}$	$3.7\ 10^{1}$	$3.0\ 10^{-1}$	3.0%
2	$2.3\ 10^{-4}$	$1.0\ 10^{-2}$	$4.4\ 10^{1}$	$3.5\ 10^{-1}$	3.5%
3	$1.8\ 10^{-4}$	$1.0\ 10^{-2}$	$5.6\ 10^{1}$	$4.4\ 10^{-1}$	4.4%
4	$1.3\ 10^{-4}$	$1.0\ 10^{-2}$	$7.7\ 10^{1}$	$6.2\ 10^{-1}$	6.2%
5	$1.0\ 10^{-4}$	$1.0\ 10^{-2}$	$1.0\ 10^{2}$	$8.0\ 10^{-1}$	8%
6	$8.0\ 10^{-5}$	$1.0\ 10^{-2}$	$1.3\ 10^{2}$	$1.0\ 10^{0}$	10%
7	$6.4\ 10^{-5}$	$1.0\ 10^{-2}$	$1.6\ 10^{2}$	$1.3\ 10^{0}$	13%
220	$8.1\ 10^{-6}$	$1.0\ 10^{-2}$	$1.2\ 10^{3}$	$9.9\ 10^{0}$	98.8%

^{241}Am inhalation of nitrate aerosol (AMAD = 5 μm)

t	m(t)	$A_{24h}(t) = MDA_{24h}$	Intake	E50 = MDD(t)	Ratio
(d)	AMAD = 5 μm	(Bq/d)	(Bq)	(mSv)	MDD(t)/LR
1	$7.7\ 10^{-4}$	$1.0\ 10^{-2}$	$1.3\ 10^{1}$	$1.3\ 10^{-1}$	1.3%
2	$6.5\ 10^{-4}$	$1.0\ 10^{-2}$	$1.5\ 10^{1}$	$1.5\ 10^{-1}$	1.5%
3	$4.9\ 10^{-4}$	$1.0\ 10^{-2}$	$2.0\ 10^{1}$	$2.0\ 10^{-1}$	2.0%
4	$3.6\ 10^{-4}$	$1.0\ 10^{-2}$	$2.8\ 10^{1}$	$2.7\ 10^{-1}$	2.7%
5	$2.6\ 10^{-4}$	$1.0\ 10^{-2}$	$3.8\ 10^{1}$	$3.7\ 10^{-1}$	3.7%
6	$2.0\ 10^{-4}$	$1.0\ 10^{-2}$	$5.0\ 10^{1}$	$4.8\ 10^{-1}$	4.9%
7	$1.5\ 10^{-4}$	$1.0\ 10^{-2}$	$6.7\ 10^{1}$	$6.5\ 10^{-1}$	6.5%
100	$9.9\ 10^{-6}$	$1.0\ 10^{-2}$	$1.0\ 10^{3}$	$9.8\ 10^{0}$	98%

^{241}Am ingestion (all compounds, $f_A = 5{,}0\ 10^{-4}$)

t	m(t)	$A_{24h}(t) = MDA_{24h}$	Intake	E50 = MDD(t)	Ratio
(d)	Soluble/Insoluble forms	(Bq/d)	(Bq)	(mSv)	MDD(t)/LR
1	$3.0\ 10^{-5}$	$1.0\ 10^{-2}$	$3.3\ 10^{2}$	$2.0\ 10^{-2}$	0.2%
2	$4.6\ 10^{-6}$	$1.0\ 10^{-2}$	$2.2\ 10^{3}$	$1.3\ 10^{-1}$	1.3%
3	$2.2\ 10^{-6}$	$1.0\ 10^{-2}$	$4.5\ 10^{3}$	$2.7\ 10^{-1}$	2.7%
4	$1.3\ 10^{-6}$	$1.0\ 10^{-2}$	$7.7\ 10^{3}$	$4.5\ 10^{-1}$	4.5%
5	$9.2\ 10^{-7}$	$1.0\ 10^{-2}$	$1.1\ 10^{4}$	$6.4\ 10^{-1}$	6.4%
6	$7.3\ 10^{-7}$	$1.0\ 10^{-2}$	$1.4\ 10^{4}$	$8.1\ 10^{-1}$	8.1%
7	$6.3\ 10^{-7}$	$1.0\ 10^{-2}$	$1.6\ 10^{4}$	$9.4\ 10^{-1}$	9.4%
53	$5.9\ 10^{-8}$	$1.0\ 10^{-2}$	$1.7\ 10^{5}$	$1.0\ 10^{1}$	100%

^{241}Am inhalation of type S compounds

The optimization approach suggests how to modify the procedure

$$\boxed{DL} \leq C_{S,T_m}(t) = I(\boxed{RL}) \cdot m(t) \boxed{\frac{V}{1.6} \cdot T_m \cdot Y \cdot \varepsilon \cdot \rho}$$

Optimized parameters

DL = 7,5

ε = 0,33

ρ = 0,90

RL = 10 mSv

V = 50 ml

T_m = 80.000 s

^{241}Am inhalation of type S compounds

The optimization approach suggests how to modify the procedure

$$DL \leq C_{S,T_m}(t) = I(RL) \cdot m(t) \cdot \frac{V}{1.6} \cdot T_m \cdot Y \cdot \varepsilon \cdot \rho$$

^{241}Am inhalation of type S aerosol (AMAD = 1 µm)

t	m(t)	$A_{24h}(t) = MDA_{24h}$	Intake	E50 = MDD(t)	Rapporto
(d)	AMAD = 1 µm	(Bq/d)	(Bq)	(mSv)	MDD(t)/LR
1	$2.2\ 10^{-5}$	$5.5\ 10^{-3}$	$2.5\ 10^{2}$	$7.3\ 10^{0}$	36%
2	$2.1\ 10^{-5}$	$5.5\ 10^{-3}$	$2.6\ 10^{2}$	$7.6\ 10^{0}$	38%
3	$1.6\ 10^{-5}$	$5.5\ 10^{-3}$	$3.4\ 10^{2}$	$1.0\ 10^{1}$	50%
4	$1.2\ 10^{-5}$	$5.5\ 10^{-3}$	$4.6\ 10^{2}$	$1.3\ 10^{1}$	66%
5	$9.0\ 10^{-6}$	$5.5\ 10^{-3}$	$6.1\ 10^{2}$	$1.8\ 10^{1}$	89%

^{241}Am inhalation of type S aerosol (AMAD = 5 µm)

t	m(t)	$A_{24h}(t) = MDA_{24h}$	Intake	E50 = MDD(t)	Rapporto
(d)	AMAD = 5 µm	(Bq/d)	(Bq)	(mSv)	MDD(t)/LR
1	$1.3\ 10^{-5}$	$5.5\ 10^{-3}$	$4.2\ 10^{2}$	$7.2\ 10^{0}$	36.0%
2	$1.1\ 10^{-5}$	$5.5\ 10^{-3}$	$5.0\ 10^{2}$	$8.5\ 10^{0}$	42.5%
3	$8.4\ 10^{-6}$	$5.5\ 10^{-3}$	$6.5\ 10^{2}$	$1.1\ 10^{1}$	55.7%
4	$6.3\ 10^{-6}$	$5.5\ 10^{-3}$	$8.7\ 10^{2}$	$1.5\ 10^{1}$	74.2%
5	$4.7\ 10^{-6}$	$5.5\ 10^{-3}$	$1.2\ 10^{3}$	$2.0\ 10^{1}$	100%

Optimized parameters

- DL = 7,5
- ε = 0,33
- ρ = 0,90
- RL = 20 mSv
- V = 100 ml
- T_m = 80.000 s

CONCLUSIONS:

- This method based on the concept of minimum detectable dose, *applicable to all the internal contamination measurement technique* giving as a result counts, enable to identify in advance all the parameters that mostly affected the definition of a procedure suitable to reveal all the contamination exceeding a pre-established reference dose level, allowing also the calculation of the *time useful* for sample collection.

- The same procedure here presented is suitable for the determination of Curium isotopes, in much the same way as Am.

- Simplifying procedures already used in routine monitoring, this approach ensures that laboratory should be always ready to face an emergency situation.

Thank you for listening

daniela.gorietti@enea.it