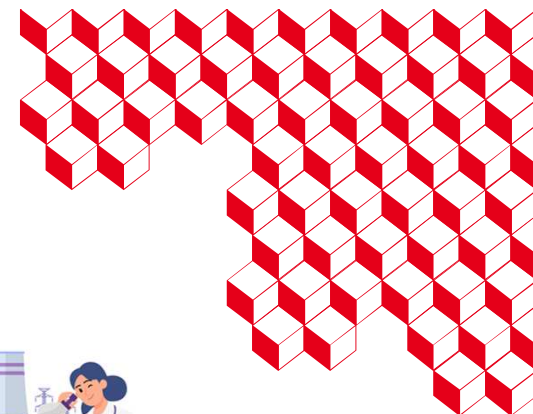


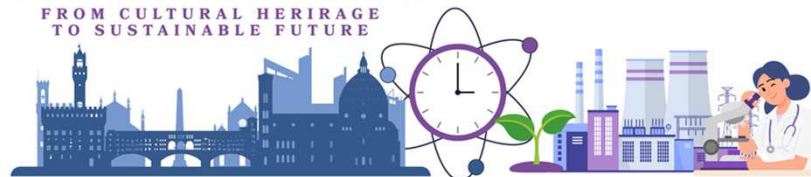


MetroPOEM



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ISOTOPIC TIME MACHINE
FROM CULTURAL HERITAGE
TO SUSTAINABLE FUTURE



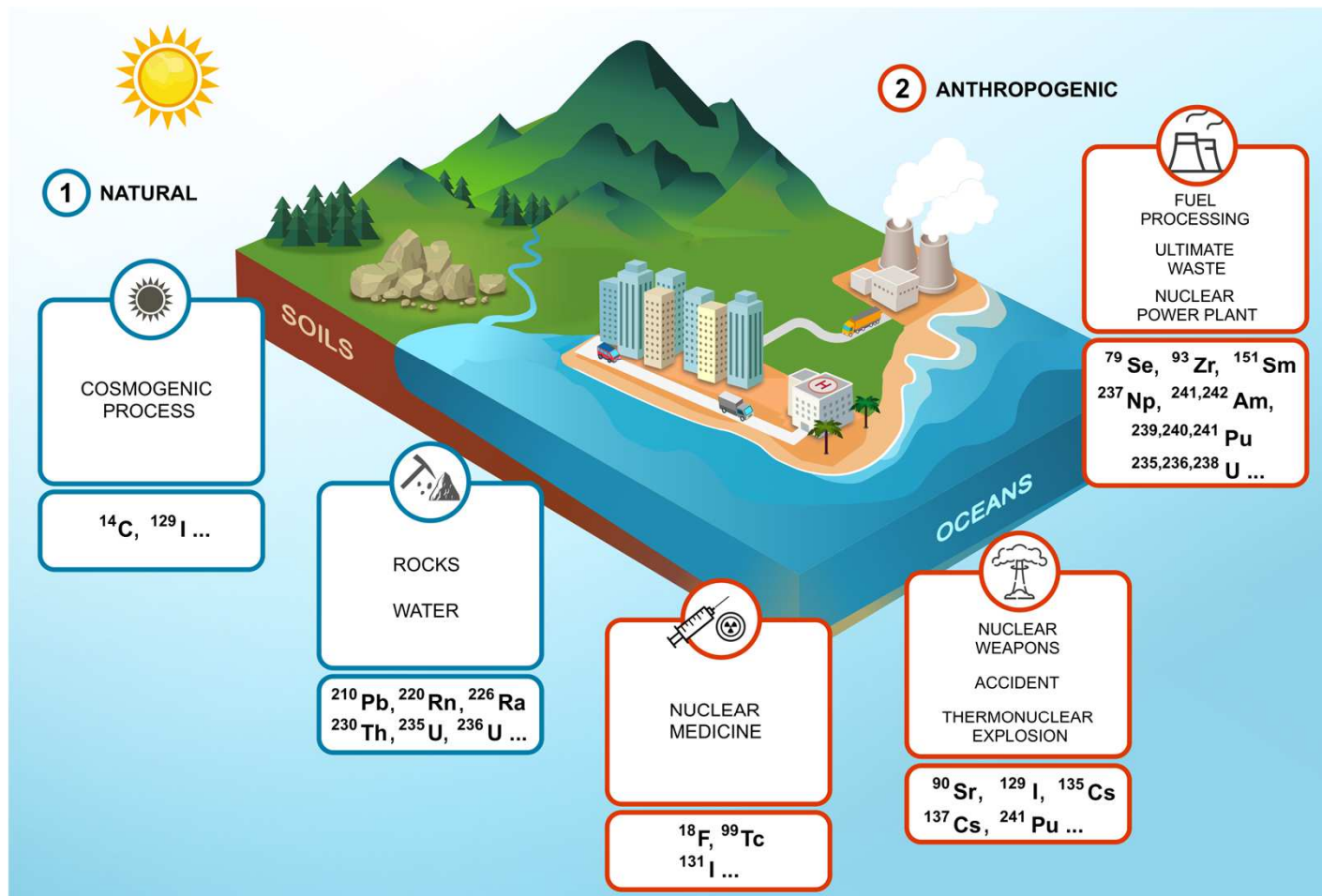
Characterisation of environmental reference materials spiked with radionuclides by mass spectrometry

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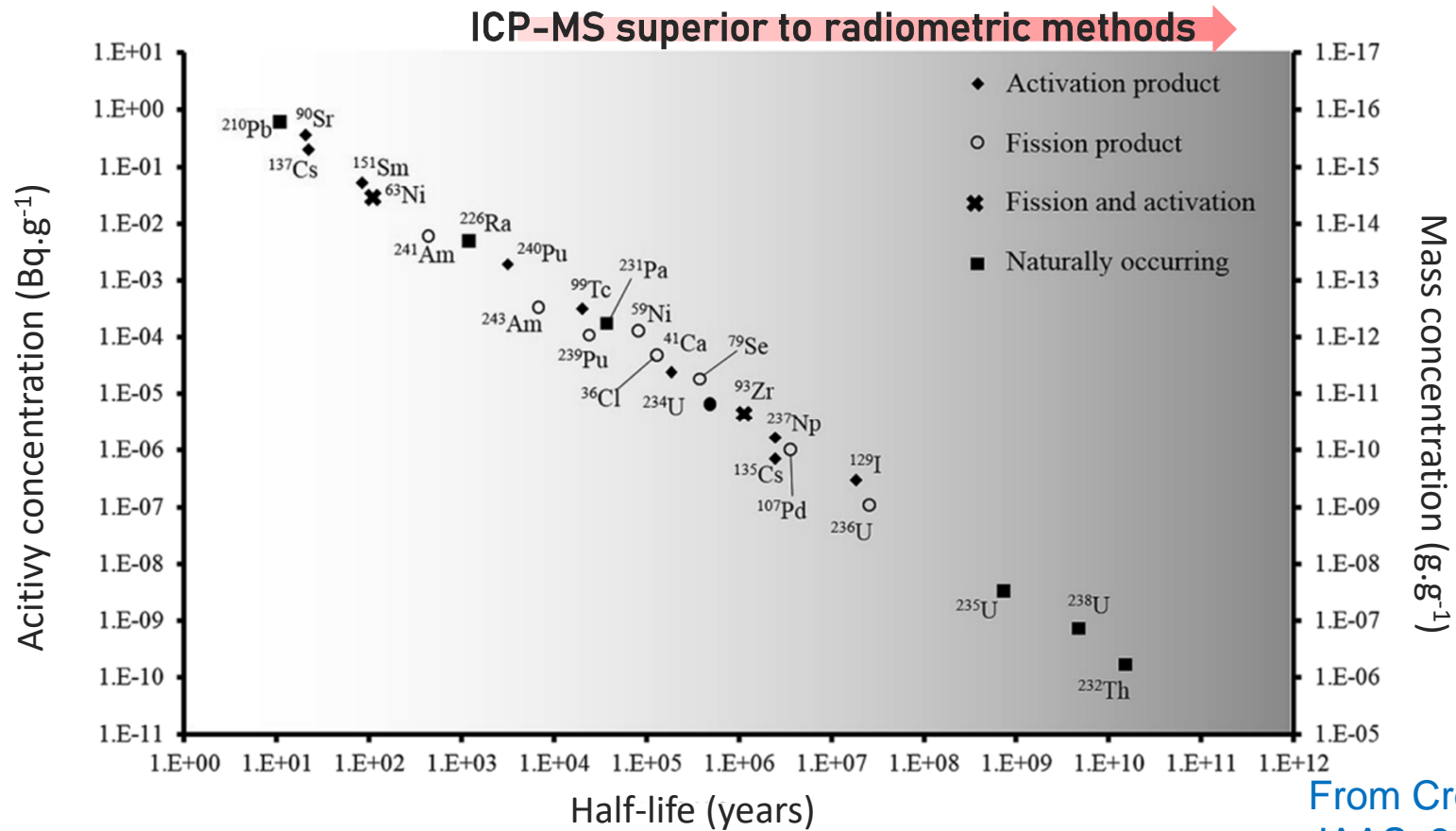
Radionuclides in the environment



From Diez-Fernandez et al.
(2020) *JAAS*, 35, 2793-2819



Mass spectrometry/ radiometric techniques



From Croudace et al. (2017)
IAAS, 32, pp. 494-526.



Mass spectrometry: isotopic fingerprinting

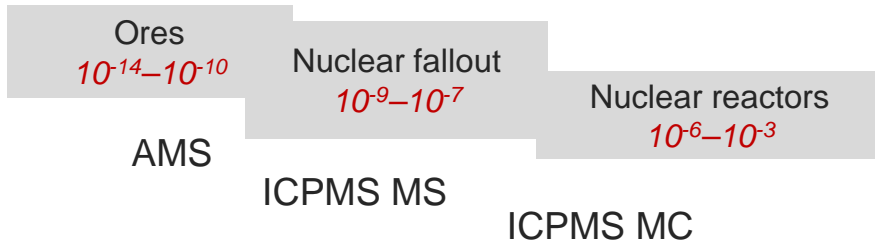
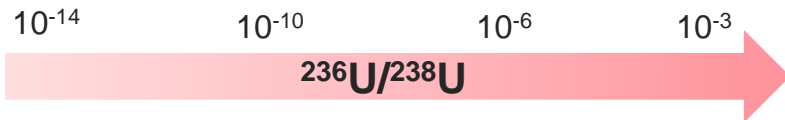


■ Uranium



²³⁶U
 $t_{1/2} = 2.34 \times 10^7 \text{ y}$

Natural source Anthropogenic source



■ Césium

¹³³Cs

¹³⁴Cs ($T_{1/2} = 2,06 \text{ ans}$)

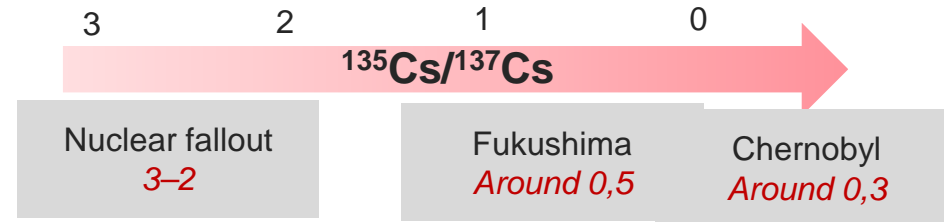
¹³⁵Cs ($T_{1/2} = 2,3 \cdot 10^6 \text{ ans}$)

¹³⁷Cs ($T_{1/2} = 30,1 \text{ ans}$)



¹³⁷Cs/¹³⁵Cs
 Source markers

- Nuclear fallout
- Variation of the isotope ratio in **reactors** in relation the burn-up and type of fuel



DRMP/SPC - LANIE



ICPMS MS

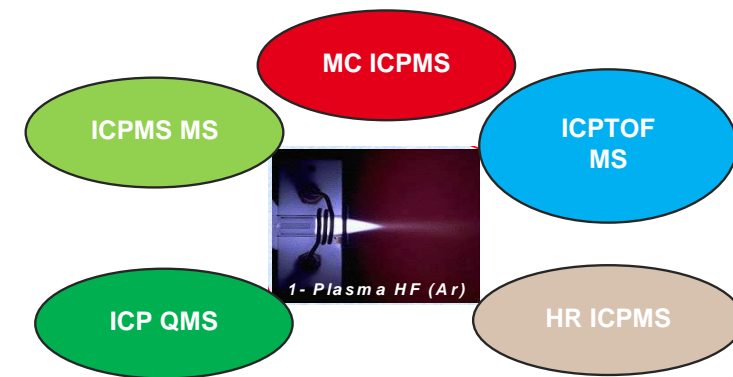
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Advantages for mass spectrometric techniques and particularly ICP MS

The place of ICP MS

- Very high sensitivity due to the plasma source (ppt-ppq)
- Precision of measurements with state of the art technique for isotope ratio measurement (ICPMS MC)
- ICP QMS and ICPMS MS are easily implemented techniques in laboratories
- Varied and diverse applications: nuclear, environment, geosciences, biomedical, qualification of isotope pure materials.

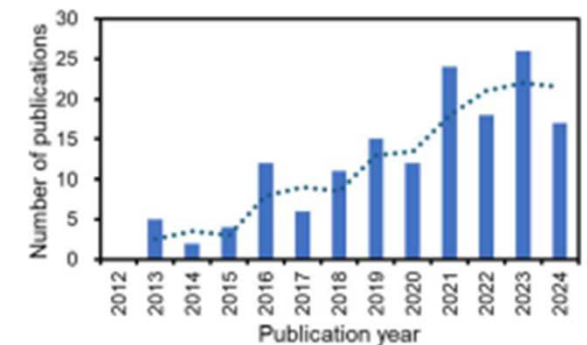
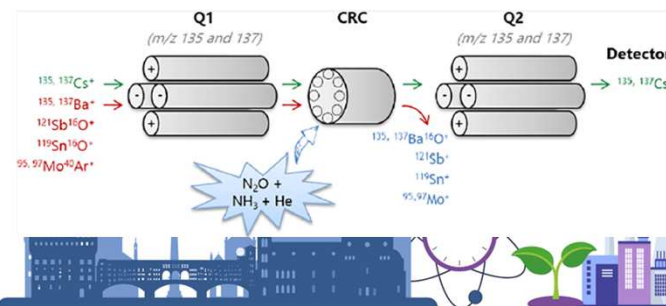
Target isotopes



Advances of ICPMS MS for isotopes

- Types of radioisotopes: ^{41}Ca , ^{90}Sr , ^{99}Tc , ^{107}Pd , ^{129}I , $^{135-137}\text{Cs}$, $^{230-232}\text{Th}$, $^{236-238}\text{U}$, $^{238-244}\text{Pu}$
- Use of collision-reaction cell with several gases: He, O_2 , CO_2 , NH_3 , H_2 , CH_3F , N_2O , CO_2 ...

From Magre et al. (2023)
Analytical Chemistry, **95**, pp.
6923-6930.



Publications on radionuclides using ICPMS MS

From Zhu et al. (2025) JAAS,
10, pp. 1428-1446.

17/02/2026



Needs for MS measurement of radionuclides

■ Protocols of radiochemistry for purification of radionuclides

- **Separative techniques:** liquid chromatography, ion exchange or solid phase extraction (UTEVA, TEVA, DGA, Sr Spec, Ln Spec...), liquid-liquid extraction
- **Spikes material** for evaluation of separation efficiency or use of isotope dilution (rarity in several cases, example of ^{236}Np)
- **Automatisation** of separation: in case of emergency or for routine control measurements

■ Need of certified reference materials (CRM)

- Certified CRM for **calibration of mass spectrometer** (mass bias, isotope fractionation, abundance sensitivity, detectors calibration...). JRC Geel (IRMM), NIST, CETAMA... → reliable to SI
- Reference materials with **similar matrix** than environmental samples. They exist (IAEA ..) but scarce and not certified **on isotope ratios**



- ➔ Major for **method validation** particularly for new technologies
- ➔ Major for **normalisation** of new analytical methods
- ➔ Major for **inter-laboratories comparisons** and isotopic fingerprinting



Objectives of the METROPOEM project



■ METROPOEM: Metrology for the harmonisation of measurements of environmental pollutants in Europe

- Development of **highly sensitive techniques** to detect ultra-low levels of radioactive and stable pollutant elements and their **isotope ratios** identified as environmental stressors
- 24 european laboratories on **metrology** (PTB, CEA, NPL, Tubitak, JSIL, NMBU..)
- Link between radiometric and mass spectrometry, bridging the gap between activity (**Bq**) and the amount of substance (**mol**) of an isotope
- Measurement by different techniques of mass spectrometry of **radioactive pollutants** (U, Pu, Am, Np, Sr)
- Fabrication and certification of **certified reference material** (CRM) in environmental matrix **linked to SI**



OUTPUTS FROM EURAMET PROJECT 21GRD09 – MetroPOEM



Simon Jerome (NMBU, Ås, Norge) and the MetroPOEM consortium (<https://www.npl.co.uk/euramet/metropoem>)
simon.mark.jerome@nmbu.no

Poster session

<https://www.npl.co.uk/euramet/metropoem>



DRMP/SPC - LANIE



17/02/2026

Two certified reference materials: doping solutions



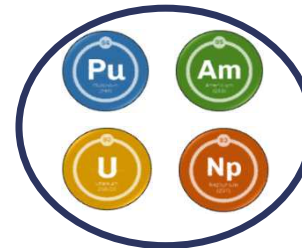
Doping Radioactive solutions



4 individual
solutions
ppm level



Mixing of the 4
radionuclides
ppm and ppb level



Mixing with
environmental matrix
at ppb and ppt levels



→ Accurate isotope ratios TIMS and MC ICPMS associated to DI linked to SI

→ Short and long term stability and Homogeneity tests



Results on isotopic measurements for doping solutions



MetroPOEM



ALONE SOL



TIMS, MTE method

MIX SOLUTION

ICPMS MC



CRM Sea water

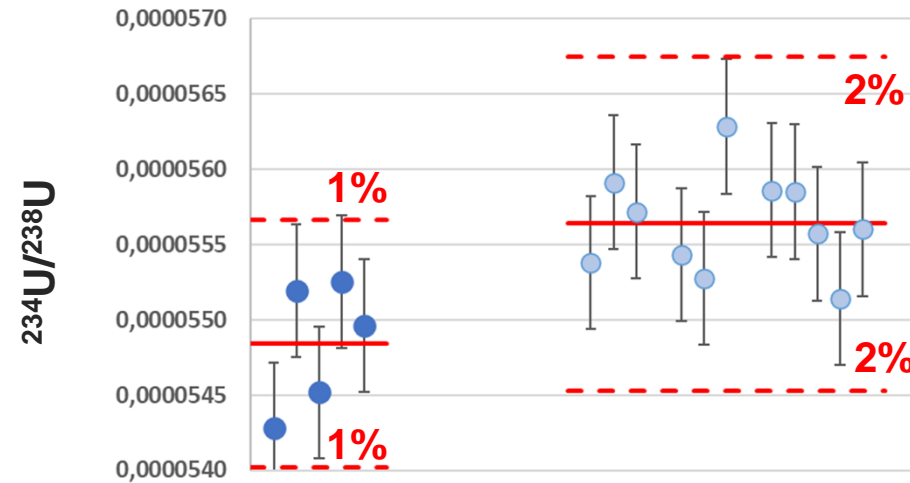
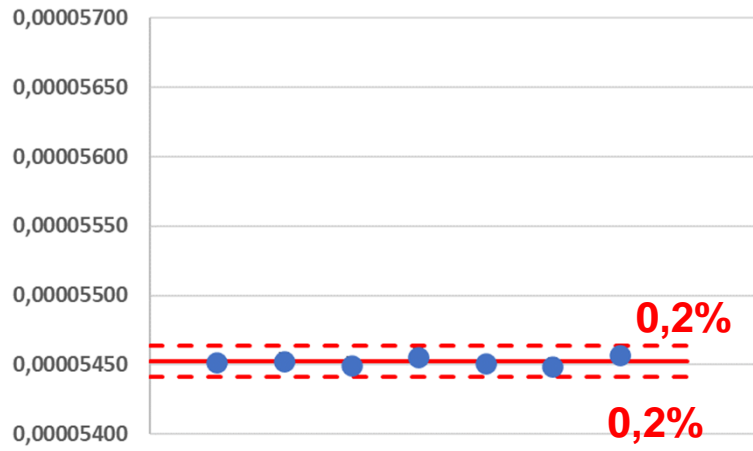
ICPMS MC

SEAWATER

$^{234}\text{U}/^{238}\text{U}$

=0,0000633(1)
[U]~0,003 $\mu\text{g}\cdot\text{g}^{-1}$

$^{234}\text{U}/^{238}\text{U}$



→ Coherence with gravimetry

[U] = 4027 (10) $\mu\text{g}\cdot\text{g}^{-1}$
(0,25%)

[U] = 13,79 (4) $\mu\text{g}\cdot\text{g}^{-1}$
(0,26%)

[U] = 0,03697 (18) $\mu\text{g}\cdot\text{g}^{-1}$
(0,5%)

Determined by DI using ^{235}U spike linked to SI



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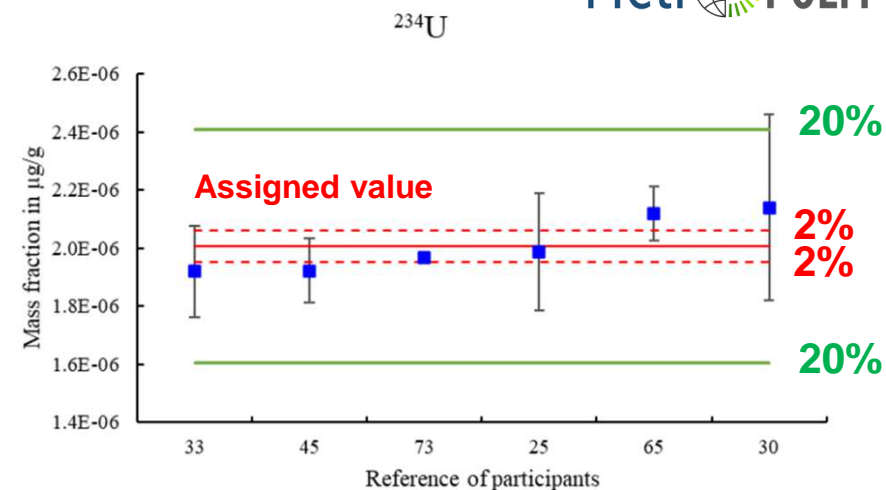
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Interlaboratory comparison exercise



LIQUID CRM

	Conc.	Isotope ratio
U	0,04 $\mu\text{g.g}^{-1}$	Nat.
Pu	0,0006 $\mu\text{g.g}^{-1}$	240/239~0,1
²⁴¹ Am	0,0009 $\mu\text{g.g}^{-1}$	-
²³⁷ Np	0,0004 $\mu\text{g.g}^{-1}$	-



SOLID CRM

	Conc.	Isotope ratio
U	0,03 $\mu\text{g.g}^{-1}$	Enr. 1% ²³⁵
Pu	0,001 $\mu\text{g.g}^{-1}$	239/240~0,02
²⁴¹ Am	0,0004 $\mu\text{g.g}^{-1}$	-
²³⁷ Np	0,0005 $\mu\text{g.g}^{-1}$	-

Techniques used	Number of lab
MC ICPMS	1
Q ICPMS	1
ICPMS MS	3
HR ICPMS	1





Conclusions

■ Fabrication and qualification of CRM spiked with radionuclides for establishment of analytical methods by mass spectrometry

- CRM linked to SI: liquid material (seawater) and solid (silicate)
- CRM qualified in **isotope ratios (U and Pu)** and **contents**



Two SI traceable CRM doped in radionuclides available for the community

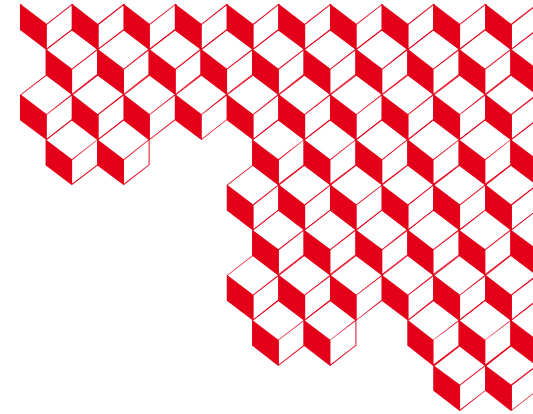
■ Mass spectrometric analysis of long-live radionuclides by mass spectrometry

- **Guide** for use of mass spectrometry for detection of radionuclides in environment by mass spectrometry
- Large development of analytical method by **ICPMS MS** and implementation of this techniques on laboratories





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Thanks



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