



UNIVERSITÀ
DEGLI STUDI
DI MILANO



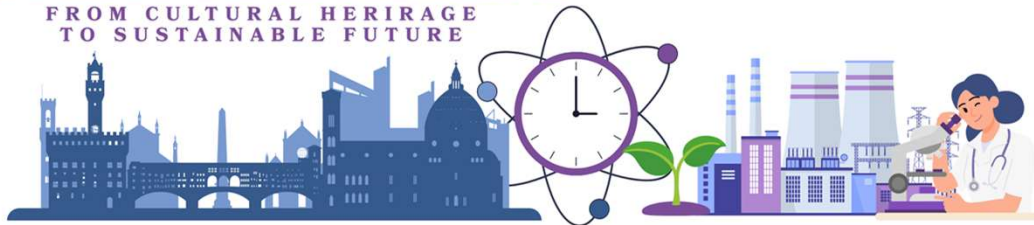
Radioanalytical determinations and radioactivity measurements in the field of Radiation Protection: the experience of the Integrated Laboratory of Radioactivity Measurement and Monitoring of the ENEA Radiation Protection Institute

S. Ridone, D. Arginelli, M.C. Botta, D. Goriatti, F. Modestia, S. Zicari, D. Pirullo, P. Battisti
Radiation Protection Institute - Integrated Laboratory of Radioactivity Measurement and Monitoring



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

ISOTOPIC TIME MACHINE
FROM CULTURAL HERITAGE
TO SUSTAINABLE FUTURE





Summary

- ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development)
- Radiation Protection Institute (IRP)
- Integrated Laboratory of Radioactivity Measurement and Monitoring (IRP-MIR)
- Determination of radionuclides in biological and environmental samples
- Quality Control and Quality Assurance



ENEA – Italian National Agency for New Technologies, Energy and Sustainable Economic Development

- ENEA is a public body aimed at research, technological innovation and the provision of **advanced services to enterprises, public administration and citizens** in the sectors of energy, the environment and sustainable economic development
- ENEA has highly qualified personnel, advanced laboratories, experimental facilities and excellent instruments for the realization of **projects, studies, tests, assessments, analyses and training services**, with particular reference to product and process innovation and the valorization of results to contribute to the development and competitiveness of the national economic system.
- Since its foundation in the 1960s, its strengths have been applied **research, technology transfer and technical-scientific support** to companies, associations, territories, central and local administrations: for this reason - unlike other research institutions - the Agency depends on the Ministry of the Environment and Energy Security.

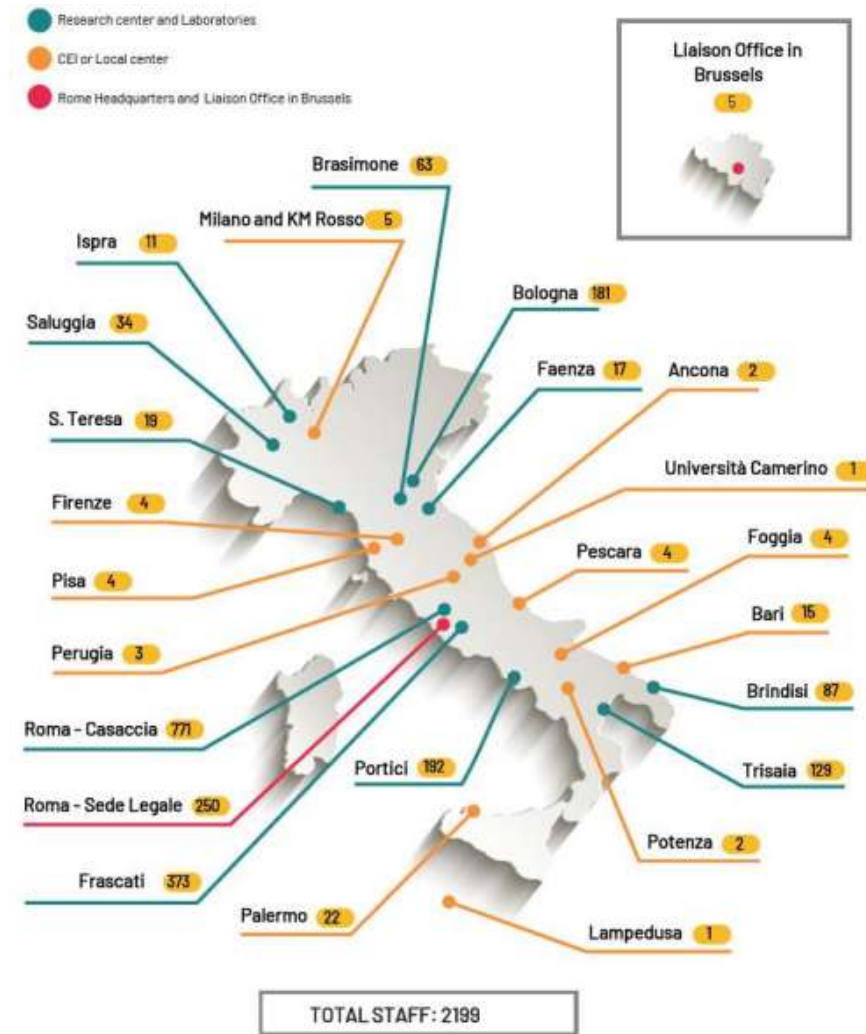


Figure - Geographic allocation of staff as of June 30, 2025



Focus sectors





ENEA Radiation Protection Institute (IRP)



External dosimetry service (IRP-DOS)

- Calibration of radiation protection equipment (accredited calibration laboratory, LAT)
- Radon and natural radionuclide level measurements



Operational radiation protection service (IRP-SIL)

- Radiation safety for facilities exposed to ionizing radiation



Environmental contamination monitoring service (IRP-AMB)

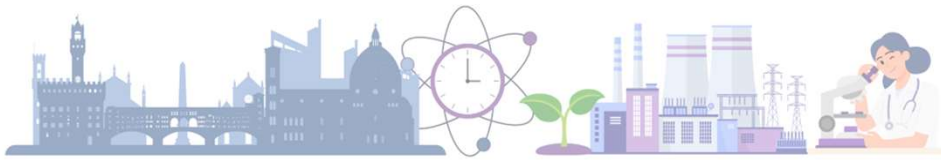
- Detecting radioactivity levels in environmental samples



Internal contamination monitoring service (IRP-MIR)

- Assessing internal contamination through «in vivo» (Whole Body Counter) or «in vitro» measurements





Integrated Laboratory of Radioactivity Measurement and Monitoring (IRP-MIR)

➤ It provides **advanced technical services for:**

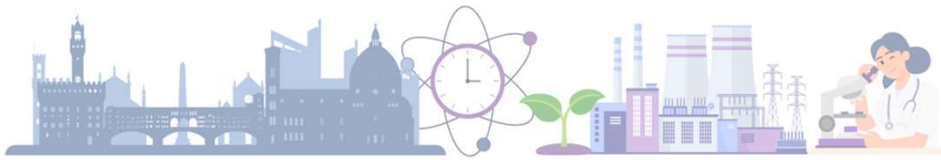
- **internal contamination monitoring**

in vivo measurements
(Whole Body Counter)

in vitro analysis on biological samples
(Radiotoxicology)

- **radiometric measurements**

environmental and food samples,
waste samples deriving from decommissioning, etc...



Integrated Laboratory of Radioactivity Measurement and Monitoring (IRP-MIR)

➤ It provides **advanced technical services for**

- **internal contamination monitoring**
- **radiometric measurements**

➤ It promotes and carries out studies in order to implement optimized techniques for the measurement of radioactivity in different matrices according to a radiation protection interest.





Measurement techniques



Alpha spectrometry

(after radiochemical treatment)



Gamma spectrometry



Proportional counting

(Gross alpha/beta counting)



Liquid scintillation counting

(also with Cherenkov effect)



ICP-MS spectrometry



Radiochemical lab. (Casaccia)

Daniela Gorietti- daniela.gorietti@enea.it

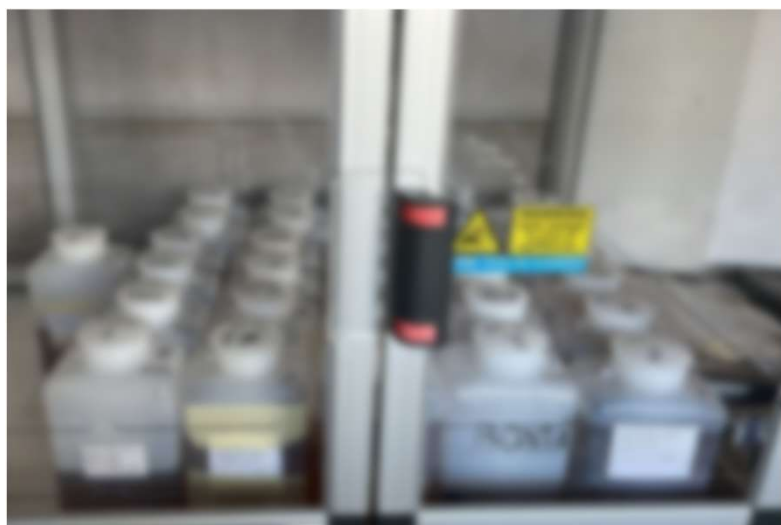


Measured radionuclides

- Artificial actinides: ^{238}Pu , $^{2389+240}\text{Pu}$, ^{241}Pu , ^{241}Am , ^{244}Cm , ^{242}Cm
- Natural actinides: Uranium/Thorium isotopes
- ^{90}Sr
- $^{210}\text{Pb}/^{210}\text{Po}$
- ^{226}Ra , ^{228}Ra
- ^3H , ^{14}C
- Gamma emitters
- Beta emitters



2025

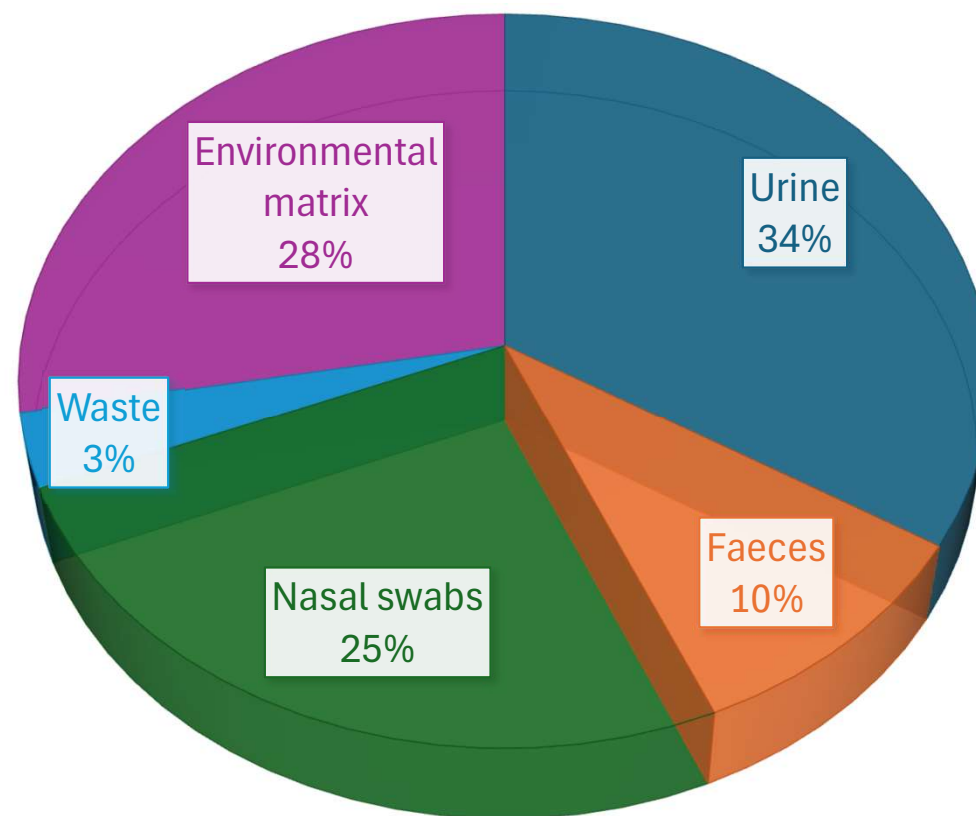




2025 samples ranked by matrix

Total number of samples analysed
in 2025

3400

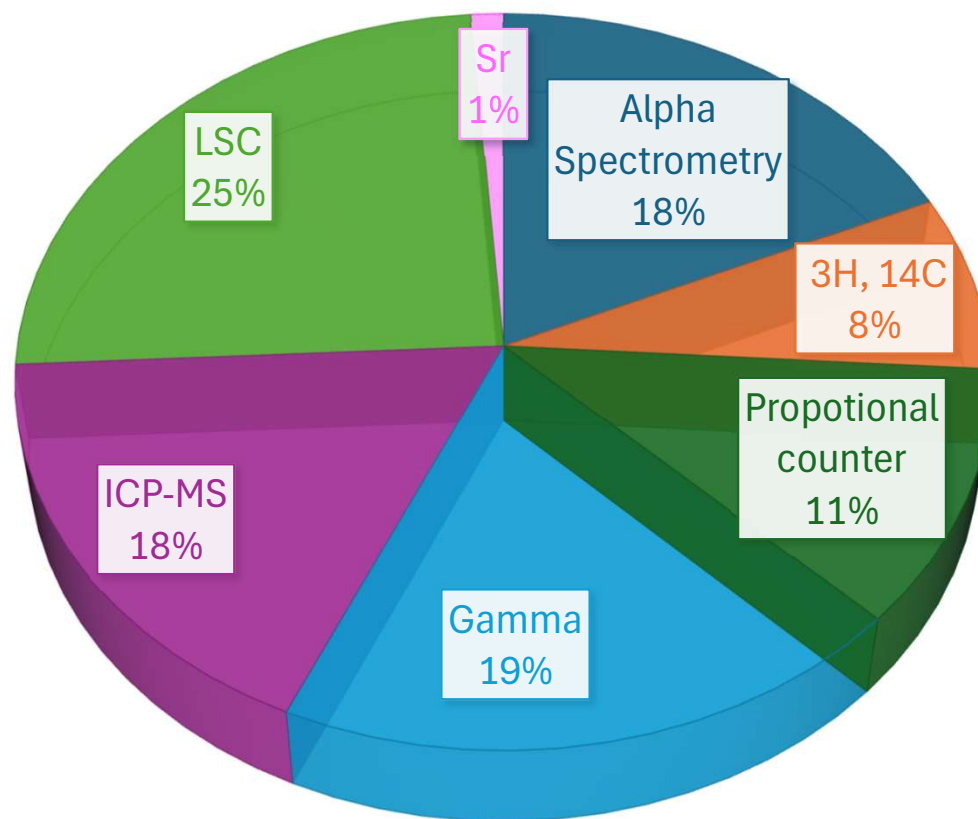




2025 samples ranked by analysis techniques

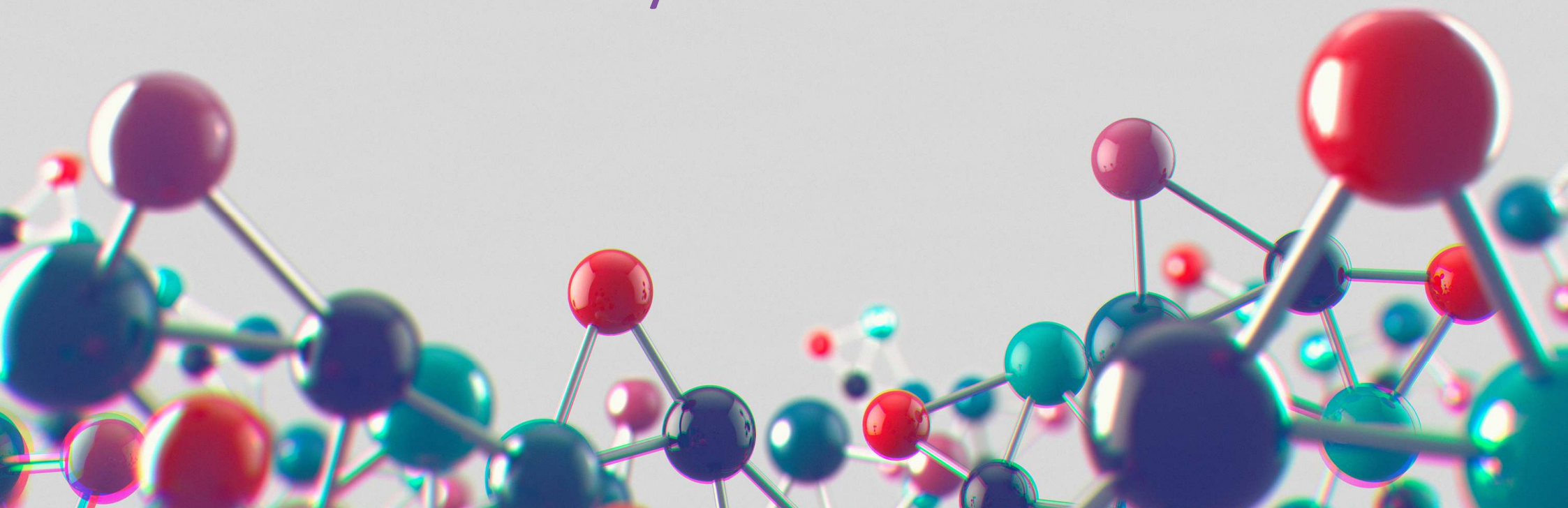
Total number of samples analysed
in 2025

3400





An insight into some analytical methods





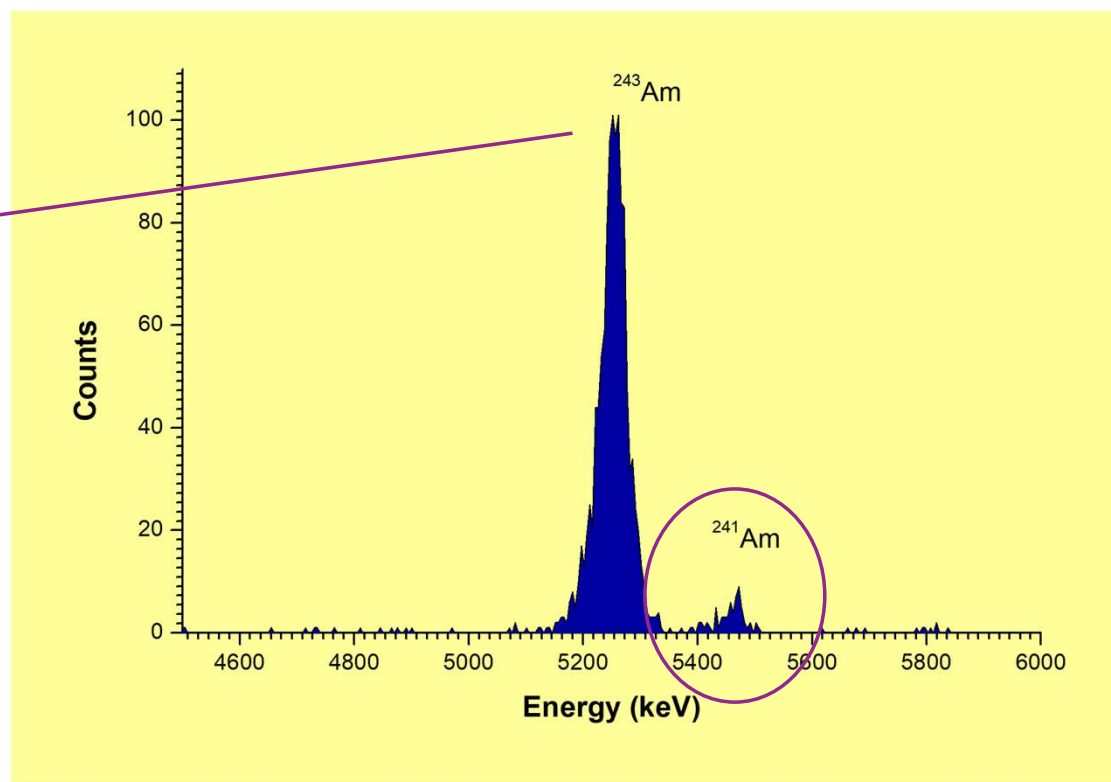
Actinides in biological samples (urine or fecal ashes)

- Use of ^{242}Pu and ^{243}Am as internal standards
- Sample mineralization with conc. HNO_3
- For urine: coprecipitation with phosphate salt and isolation of the precipitate.
- Residue dissolution in HNO_3
- Sequential chromatographic separation of Plutonium and Americium.
- Electroplating and measuring by alpha spectrometry



Actinides in biological samples (urine or fecal ashes)

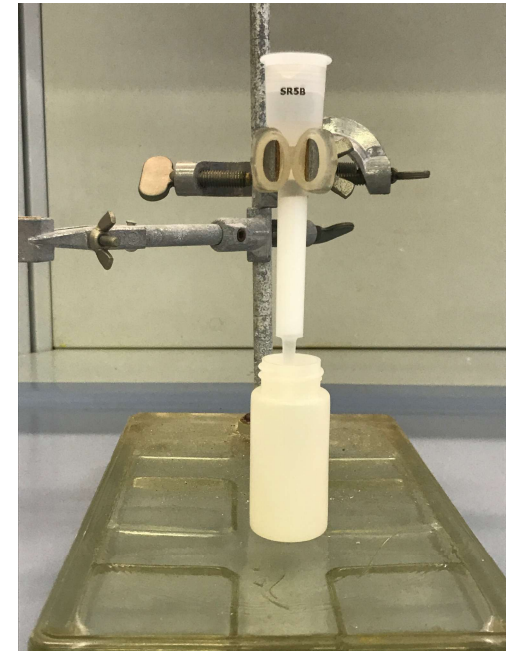
Tracer

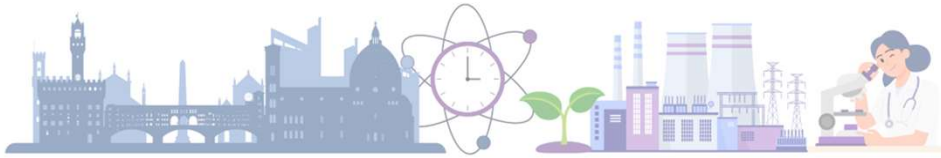




^{90}Sr in water and urine samples

- Sample mineralization
- Separation by Sr Resin ColumnTM:
 - Yttrium discard
 - Strontium retention and subsequent elution
- ^{90}Y ingrowth Cherenkov measurement by QuantulusTM Ultra Low Level LSC
- Determination of ^{90}Sr activity before secular equilibrium $^{90}\text{Sr}/^{90}\text{Y}$ by a mathematical fit by equation:
$$y = A \cdot (1 - e^{-\lambda t}) + B$$





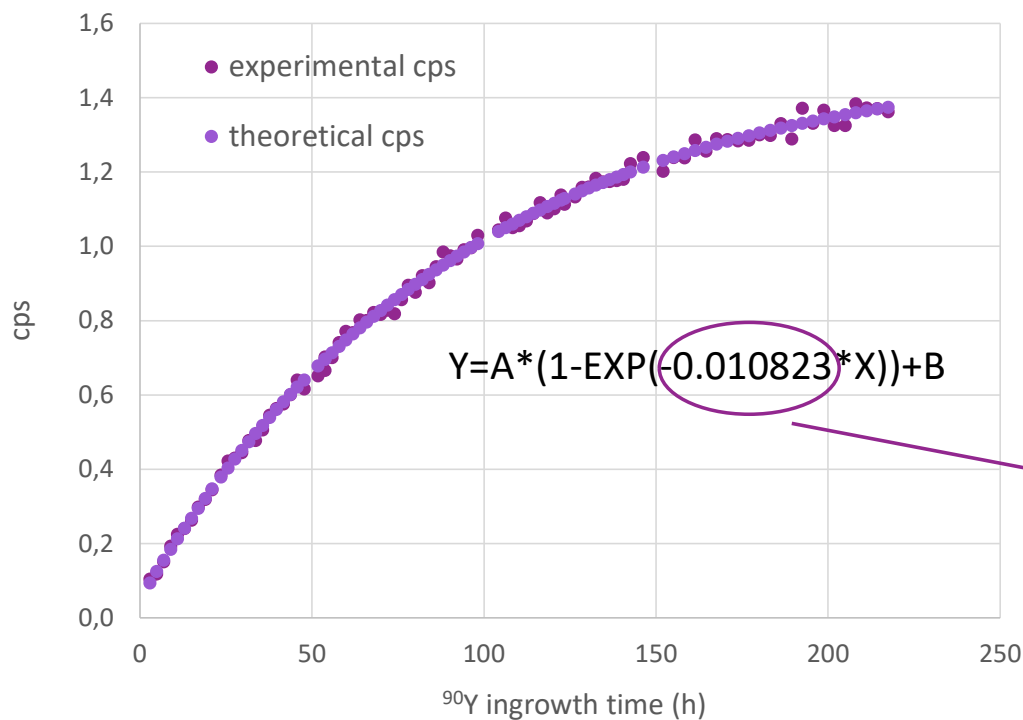
^{90}Sr in water and urine samples

Y-90 LSC spectrum



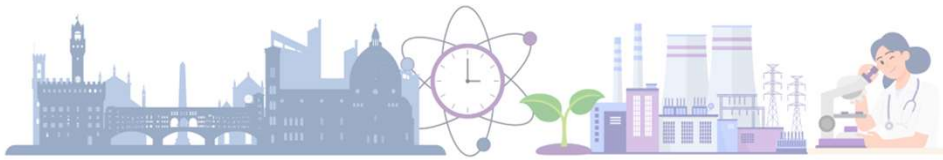


⁹⁰Sr in water and urine samples



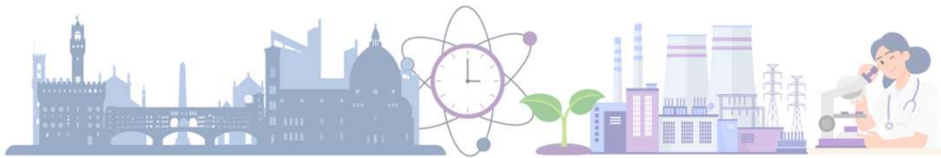
$$y = A \cdot (1 - e^{-\lambda t}) + B$$

\downarrow \downarrow \downarrow
⁹⁰Y activity (⁹⁰Sr activity) at the equilibrium (cps) spurious beta contribution (cps)
⁹⁰Y decay constant (h⁻¹)

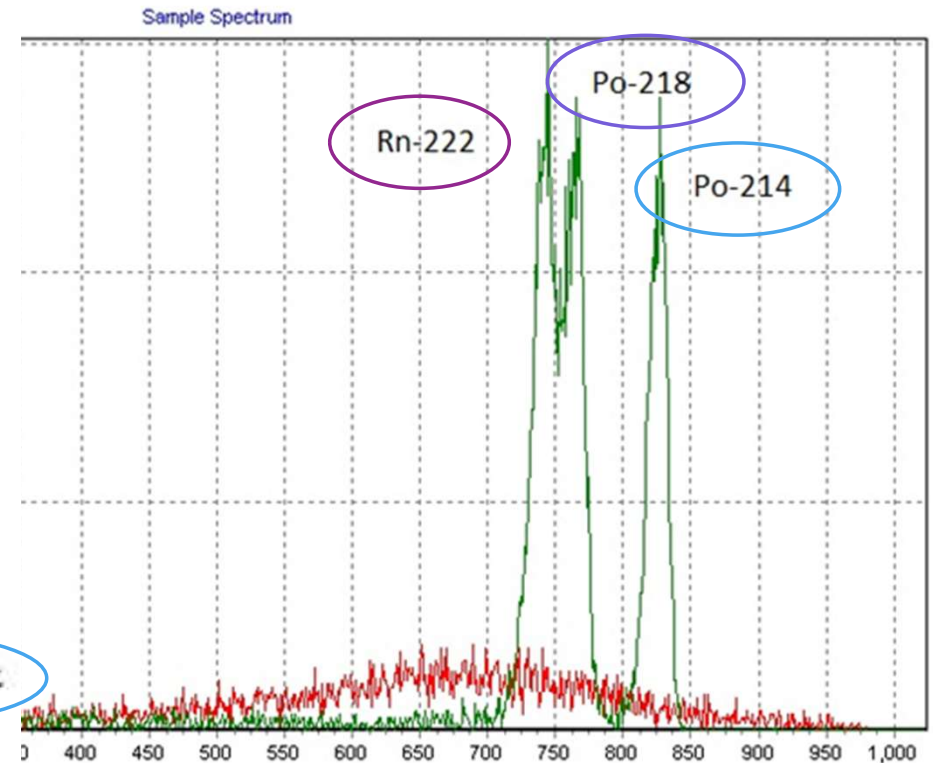
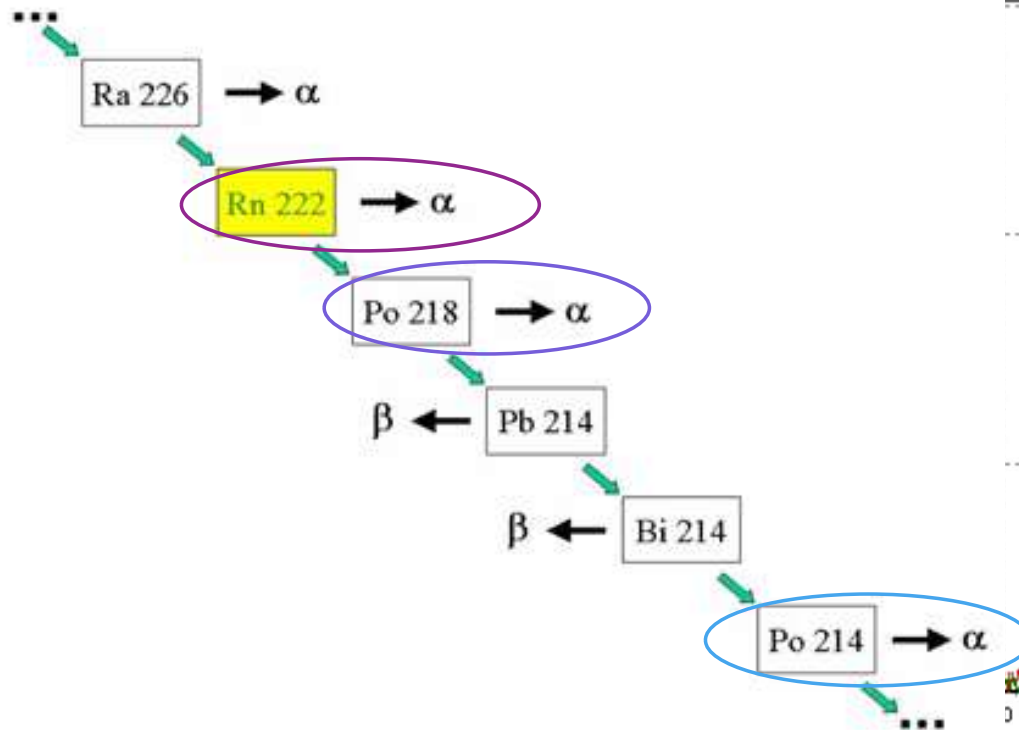


Liquid Scintillation Counting for ^{226}Ra in water and urine

- After mineralization and co-precipitation of MnO_2 with Ra e Ba (only for urine samples), transfer of the sample into PTFE vial
- Addition of 10 mL of Ultima Gold F or Mineral Oil cocktail → **immiscible** with water → separation in two phases
- ^{222}Rn drifts to upper phase
- After 30 days secular equilibrium reached $^{226}\text{Ra}/(^{222}\text{Rn}+^{218}\text{Po}+^{214}\text{Po})$
- Determination of ^{226}Ra activity before secular equilibrium by a mathematical fit with an exponential function

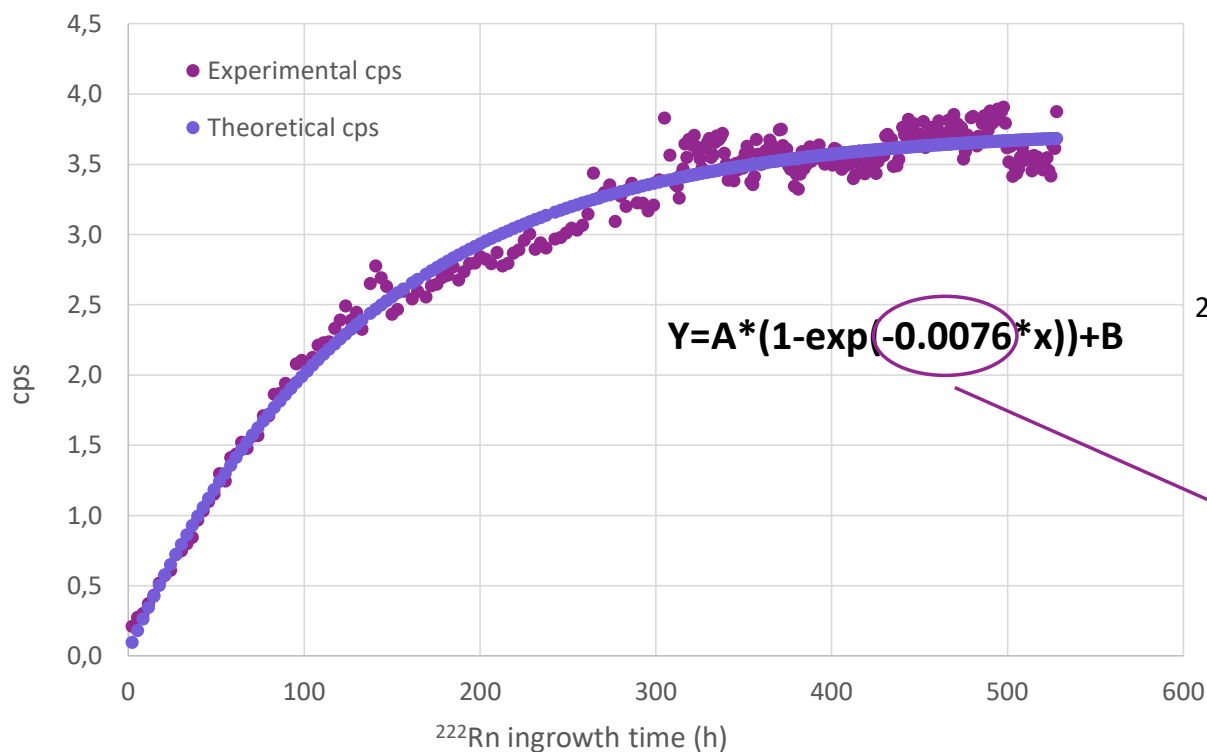


Liquid Scintillation Counting for ^{226}Ra in water and urine





Liquid Scintillation Counting for ^{226}Ra in water and urine



$$y = A \cdot (1 - e^{-\lambda t}) + B$$

^{222}Rn activity (^{226}Ra activity)
 at the equilibrium
 (cps)

spurious alpha
 contribution
 (cps)

^{222}Rn decay constant
 (h^{-1})



Determination of ^{234}U / ^{235}U / ^{238}U and ^{232}Th by ICP - MS

Instrumentation

Agilent 7700 ICP-MS
(Inductively Coupled Plasma Mass Spectrometer) equipped with
Helium Collision Cell

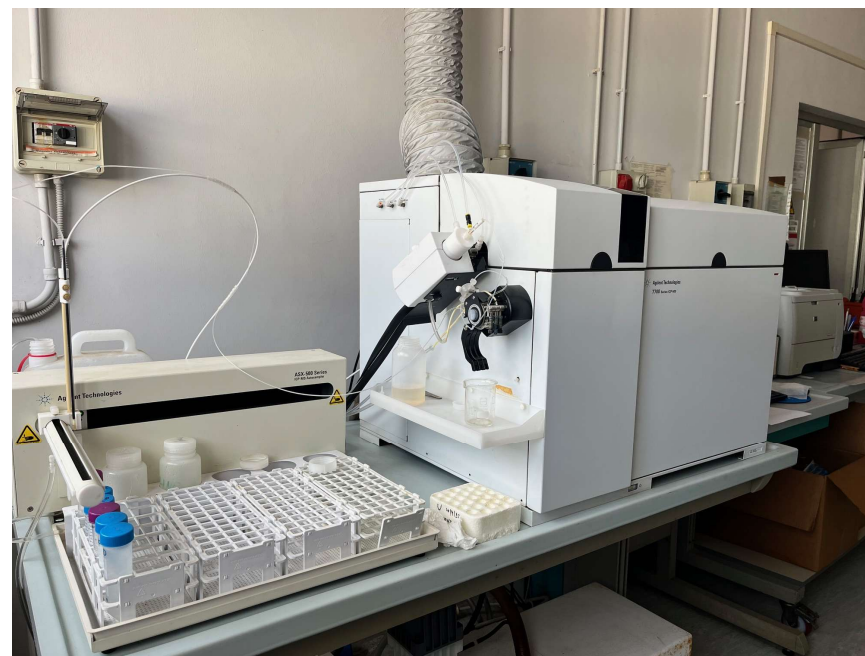




Determination of ^{234}U / ^{235}U / ^{238}U and ^{232}Th by ICP - MS

Principles of technique

- Liquid samples are **nebulised** in the sample introduction system, creating a fine aerosol that is subsequently transferred to the argon plasma.
- The high-temperature plasma **atomises** and **ionises** the sample, generating ions which are then extracted through the interface region and into a set of electrostatic lenses called the ion optics.
- The ion optics **focuses** and guides the ion beam into the **quadrupole mass analyser**.
- The mass analyser separates ions according to their mass-charge ratio (m/z), and these ions are measured at the detector.

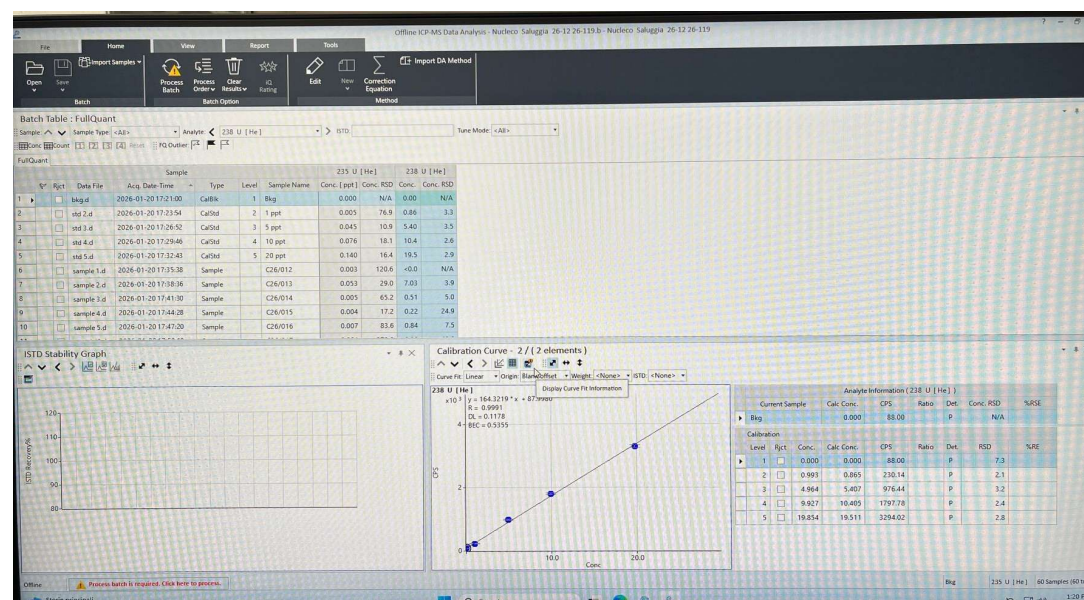




Determination of ^{234}U / ^{235}U / ^{238}U and ^{232}Th by ICP - MS

Quantitation

- The signal acquired by the detector is quantified by external standardization through a calibration curve for each isotope
- The calibration range is [1;20] ppt ^{238}U
- The instrumental Detection Limit is 0,1 ppt

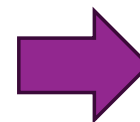
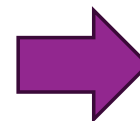




Determination of ^{234}U / ^{235}U / ^{238}U and ^{232}Th by ICP - MS

Application:

- Uranium and Thorium detection and quantitation in workers urine samples (Method Detection Limit 1,2 ppt of ^{238}U);
- Uranium and Thorium detection and quantitation in process waters and decommissioning waste;
- Uranium and Thorium detection and quantitation in soils, rocks and groundwaters.





Quality Control and Quality Assurance





Quality Control and Quality Assurance

Laboratory QC and QA are guaranteed by:

- wide usage of Certified Reference Materials (CRMs), if available;
- participation to proficiency tests proposed by the most accredited national and international organizations (ALMERA, PROCORAD, IRSN, CONVEX-3, JRC-REM, EURADOS...).



PROCORAD

(Association for the PROMotion of quality CONTROL of medical biology analyses in RADiotoxicology)

20 y

Non-profit association under the French law of 1901

Missions, History and Organization

- Missions**: PROCORAD organises intercomparisons in the field of radiotoxicology in order to control the quality of medical analysis results and promote good laboratory practices.
- History**: PROCORAD is a non-profit association created in November 1995 on the initiative of biological pharmacists.
- Organization**: The Board of Directors of PROCORAD is composed of nine representatives per founding member of the Procordan Association.

The teams at your disposal

- Procordan's key functions**: Chair, Treasurer, Quality, Secretariat and Webmaster...
- Scientific Advisory Board**: The Scientific Council's main mission is to support the technical operations of the PROCORAD association.
- Service provider laboratories**: The service laboratories are responsible for designing the intercomparisons.

Intercomparisons

- Suggested intercomparisons**: Discover all our different intercomparisons...
- Calendar**: Intercomparison schedule - (timeline).
- Annual meeting**: Attend the annual meeting and benefit from discussions between participants.

Join the Procordan association | Participate in annual intercomparisons

News

- Annual meeting 2026: Warsaw - 25 January 2026
- Intercomparisons 2026: Registration now open - 3 November 2025

Links

- Procordan association
- Annual meeting
- Member
- Adherent
- Overview
- Contact us
- FAQ

© 2026 Procordan WordPress Theme by Gutmmer & Neuwly

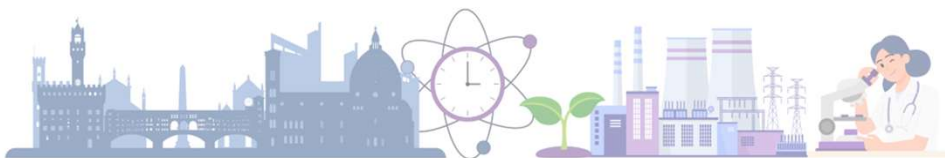
IRP-MIR labs regularly participates to annual intercomparison exercises promoted by PROCORAD, for the determination of different radioisotopes in excreta

Sample matrix	Radionuclide(s)	Measurement technique(s)	IRP-MIR Lab. participating
Urine	^3H	Liquid scintillation counting	Casaccia, Saluggia, Trisaia
Urine	Organically bound ^3H	Liquid scintillation counting	Casaccia, Saluggia, Trisaia
Urine	^{14}C	Liquid scintillation counting	Casaccia, Trisaia
Urine	$^3\text{H} + ^{14}\text{C}$	Liquid scintillation counting	Casaccia, Trisaia
Urine	Gamma emitters	Gamma spectrometry	Casaccia, Saluggia, Trisaia
Urine	Uranium isotopes	Alpha spectrometry and ICP-MS	Casaccia
Urine	Actinides	Alpha spectrometry	Casaccia, Saluggia
Faecal ashes	Actinides	Alpha spectrometry	Casaccia, Saluggia
Urine	^{90}Sr	Liquid scintillation counting	Casaccia, Saluggia, Trisaia
Nasal swabs	Alpha emitters	Liquid scintillation counting	Casaccia, Saluggia, Trisaia
Urine + DTPA	Actinides	Alpha spectrometry	Casaccia, Saluggia
Urine	^{210}Po	Alpha spectrometry	Casaccia, Saluggia

Tab. 1 - Exercised performed by IRP-MIR labs in PROCORAD 2025 intercomparison

Daniela Gorietti- daniela.gorietti@enea.it

TOP LABOS 2025



PROCORAD proficiency Test

Actinides in Urine samples

Year	Radionuclide	Lab. Value [Bq]	Target value [Bq]	Relative bias [%]	Z score
2024	²³⁹ Pu	4,45E-03 ± 6,5E-04	4,47E-03 ± 2,1E-04	0	0,2
	²³⁸ Pu	4,93E-03 ± 6,4E-04	5,04E-03 ± 2,3E-04	-2	0,3
2025	²⁴¹ Am	5,56E-03 ± 9,0E-04	5,56E-03 ± 2,8E-04	0	0
	²⁴⁴ Cm	5,13E-03 ± 5,8E-04	5,20E-03 ± 2,6E-04	-1	-0,1



ALMERA (Analytical Laboratories for the Measurement of Environmental Radioactivity) NETWORK

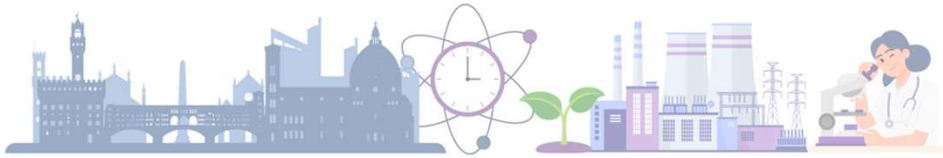
The screenshot shows the IAEA.org website with the following content:

- Navigation:** Radiometrics Lab., Radioecology Lab., Marine Environmental Studies Lab., **Terrestrial Environment Laboratory** (expanded), ALMERA network.
- ALMERA network text:** "The ALMERA network (Analytical Laboratories for the Measurement of Environmental Radioactivity) was established by the IAEA in 1995, and is a cooperative effort of analytical laboratories world-wide. Members of the network are nominated by their respective IAEA Member States as those laboratories which would be expected to provide reliable and timely analysis of environmental samples in the event of an accidental or intentional release of radioactivity. The IAEA helps the ALMERA network of laboratories to maintain their readiness by coordination activities including organization of meetings, by development of standardized methods for sample collection and analysis, and by conducting interlaboratory comparison exercises and proficiency tests as a tool for external quality control."
- ALMERA network image:** A person in a lab coat operating a piece of equipment on a tripod.
- ALMERA network image:** A petri dish containing several small, dark, circular samples.
- ALMERA network text:** "ALMERA currently consists of 126 laboratories representing 78 countries. The Agency's Environment Laboratories in Seibersdorf and Monaco are additional members of the network. A full listing of the current ALMERA member laboratories is given in the ALMERA ..."
- Links - Resources:** MEL News, History, Objectives, Programmes, Location, Contact MEL.
- Announcements:** ALMERA Workshop on Measurement Results Uncertainty Estimation and Method Validation, 12 - 16 November 2012.

IRP is an active member of ALMERA network since



Daniela Gorietti- daniela.gorietti@enea.it

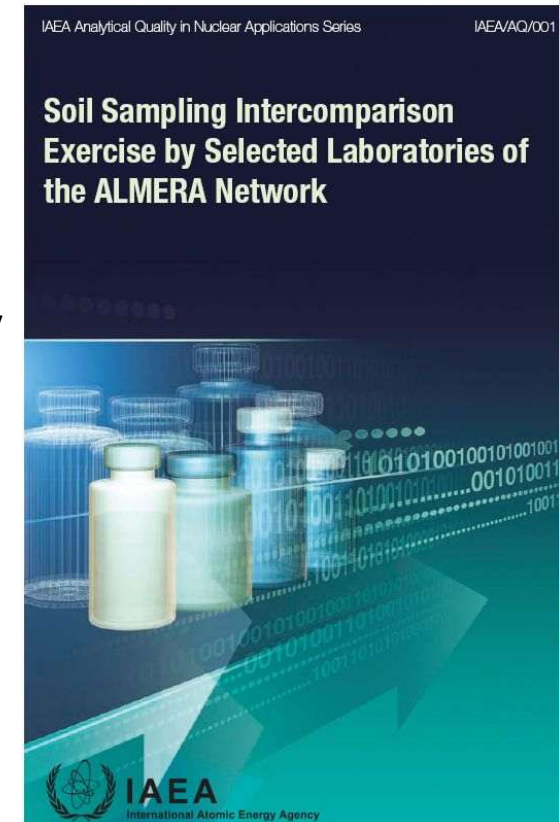


ALMERA (Analytical Laboratories for the Measurement of Environmental Radioactivity) NETWORK

The ALMERA network was established by the IAEA in 1995 and is a cooperative effort of analytical laboratories world-wide. Members of the network are nominated by their respective IAEA Member States as those laboratories which would be expected to provide reliable and timely analysis of environmental samples in the event of an accidental or intentional release of radioactivity.

ALMERA currently (September 2025) consists of 201 laboratories representing 90 countries. The Agency's Marine Environment Laboratories in Monaco and the Terrestrial Environmental Radiochemistry (TERC) Laboratory of the IAEA Physical and Chemical Sciences Division are additional members of the network. The International Atomic Energy Agency's Marine Environment Laboratories are the central coordinator of the ALMERA network's activities.

The IAEA helps the ALMERA network of laboratories to maintain their readiness by coordination activities including organization of meetings, **development of standardized methods for sample collection and analysis**, and **organization of interlaboratory comparison exercises and proficiency tests** as a tool for external quality control.





ALMERA (Analytical Laboratories for the Measurement of Environmental Radioactivity) NETWORK

Sample ID	Sample matrix	Radionuclide(s)	Measurement technique(s)	IRP-MIR Lab. participating
1	Water	^3H , ^{90}Sr ^{210}Po gamma emitters	Liquid scintillation counting Alpha spectrometry Gamma spectrometry	Saluggia
2	Water	^{234}U , ^{235}U , ^{238}U ^{226}Ra , ^{228}Ra gross alpha, gross beta	ICP-MS Liquid scintillation counting Propotional counting	Casaccia, Saluggia
3	Soil	gamma emitters	Gamma spectrometry	Saluggia
4	Vegetables	gamma emitters	Gamma spectrometry	Saluggia
5	Filter paper	^{90}Sr ^{233}Ba	Propotional counting Gamma spectrometry	Saluggia

Tab. 2 - Exercised performed by IRP-MIR labs in ALMERA Proficiency Test 2025



ALMERA proficiency Test

⁹⁰Sr and ²³⁸U in water

Year	Radionuclide	Lab. Value [Bq/L]	Target value [Bq/L]	Relative bias [%]
2024	⁹⁰ Sr	22,8 ± 1,1	23,6 ± 1,2	-3,4
	²³⁸ U	2,22 ± 0,05	2,23 ± 0,07	0,0
2025	⁹⁰ Sr	38,5 ± 4,1	39,5 ± 2,0	-2,5
	²³⁸ U	6,27 ± 0,21	6,60 ± 0,21	-5,0



*Thank you
for your attention*

