CETAMA
Métrologie et Analyses Chimiques

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INSIDER

NUCLEAR SITE INTEGRATED CHARACTERIZATION FOR RADIOACTIVE WASTE MINIMIZATION: THE INSIDER PROJECT

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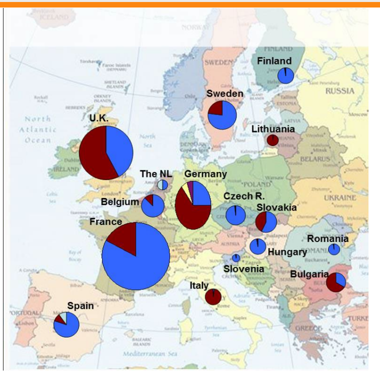
CONTENT

- Context and objectives of the INSIDER project
- Methodology
- Developments and implementation
- Preliminary benchmark results
- Perspectives and conclusions

CONTEXT

- **A global technical, societal, environmental and economic challenge for the 21st century**
  - **By 2050,** more than the half of today's 400 GW nuclear capacity around the world is scheduled to be shut down for decommissioning
  - Nuclear materials represent **a wide variety of matrices and contaminants**
- **An accurate fit for purpose radiological and chemical characterisation of facilities and sites** is required for dismantling and classification of contaminated materials.
  - Physical, radiological and non radiological characterisation prior to dismantling is a key element for all D&D projects (OECD, NEA, IAEA):
    - Scenario definition
    - Cost estimation
    - Radioactive waste production and categorisation
- **Smart applications and waste management routes** must be available to minimise the amount of radioactive waste and related potential hazard.
  - Need for reliable data to explore **different sustainable management routes** for contaminated materials: reuse, recycle…



[Sources: IAEA PRIS]

INSIDER project

Improved Nuclear SIte characterisation for waste minimisation in D&D operations under constrained EnviRonment

- A EU-funded Horizon 2020 project
  - "Research and innovation on the **overall management of radioactive waste other than geological disposal**"
  - "Management of **non-standard waste** including D&D waste"
- **4-year project:** launched in **June 2017**
- What **INSIDER will achieve**
  - To develop and validate **a new and improved integrated characterisation methodology and strategy** during nuclear decommissionning and dismantling operations (D&D) of nuclear power plants, post accidental land remediation or nuclear facilities **under constrained environments**.

→ **Results will be validated through 3 case studies**

EUG
IAEA
IRSN
ANDRA
ENRESA
SOGIN
NDF
Kraftanlaghen Heidelberg
KAERI
ORANO
IRE
ENGIE

Key objectives- Project organisation

Establish common methodologies to deploy reference guidelines

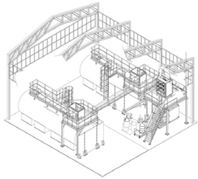
Optimise the sampling strategy under constrained conditions

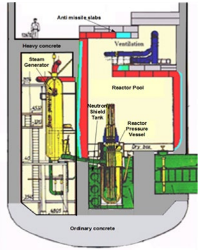
Coupling sampling/measurement:

Performance assessement of avalaible measurement techniques

Three case studies

Apply the methodologies to real worksites under decommissioning

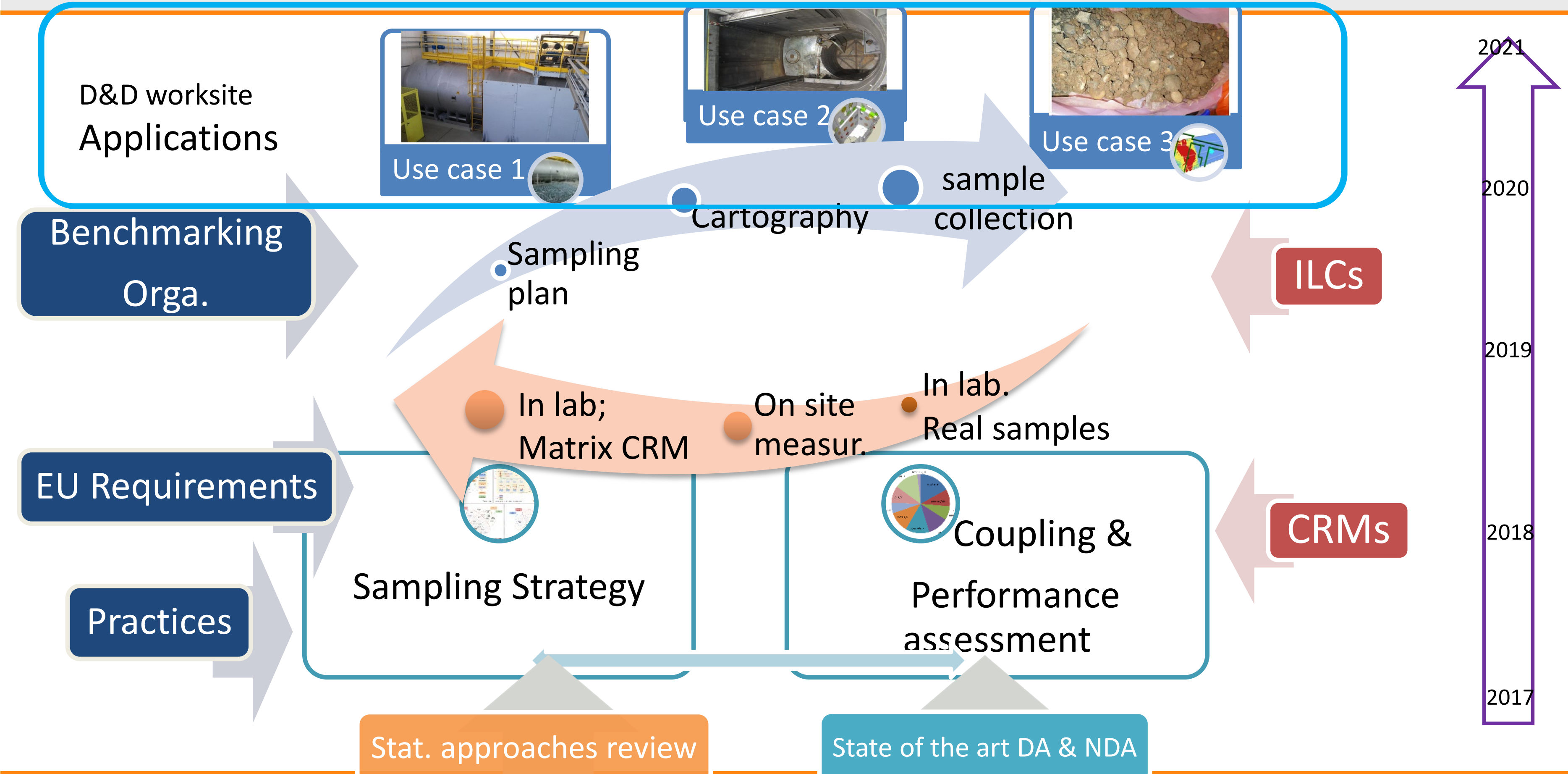


1 Decommissioning of a back/end fuel cycle and/or research facility - Ispra (JRC)

2 Decommissioning of a nuclear reactor - Mol (SCK/CEN)

3 Post accidental land remediation - (CEA)

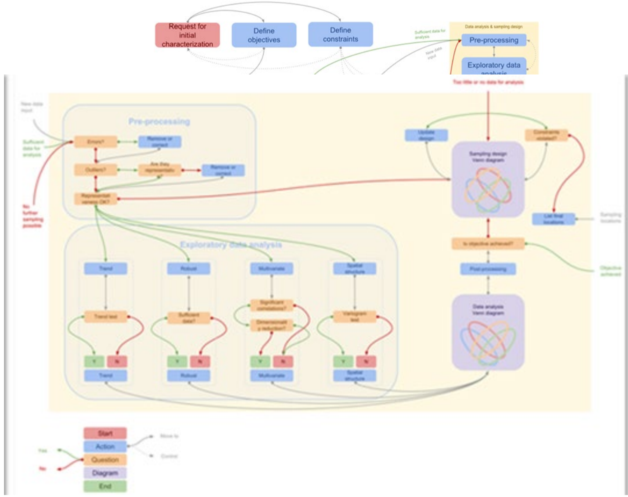
Implementation: 3 main areas



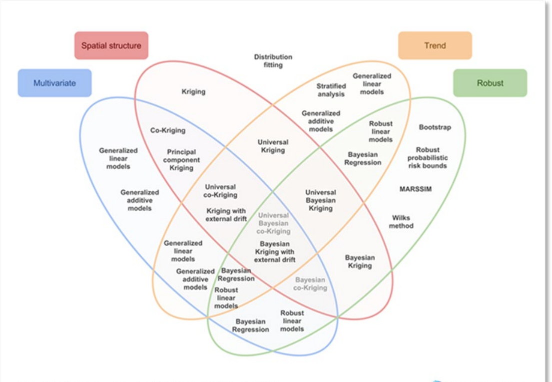
WP3

Sampling strategy

- ❑ **Global Statistical approach**
  - ❑ Support to sampling strategy and sampling design definition
  - ❑ Waste-led approach
  - ❑ Coupling sampling and characterization methods
    - ❑ gathering all possible data



- ❑ **Data analysis associated to sampling design**
  - ❑ Variables of interest and statistical indicators
  - ❑ Data processing (pre and post analysis):
  - ❑ ***Univariate or Multivariate*** data analysis
  - ❑ Presence of **Spatial structure**
  - ❑ Presence of **Spatial trends**
  - ❑ Requirement for **Robust methods**



INSIDER WP3 D2 - DATA ANALYSIS VENN DIAGRAM

INSIDER

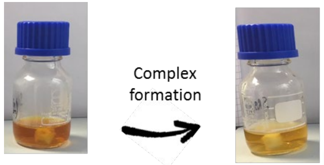
WP4

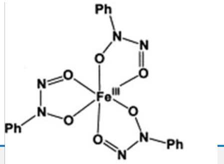
Analytical development status

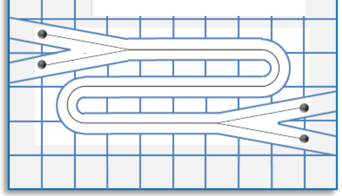
- D&D Matrix Reference materials
  - Heavy concrete: *Ba-133, Co-60, Eu-152,154*
    - *Homogenised doped real samples*
  - Effluent solution:
    - Doped solution

Main contaminants	Activity concentration range (Bq/g)
Ni-63	1-10
Sr-90	1-100
Pu-238	0.1-10
Pu-239	0.1-10
Am-241	1-10
Co-60	0.1-10
Cs-137	1-200
Fe-55	0.1-5
Pu-241	1-50
U-238	0.1-10

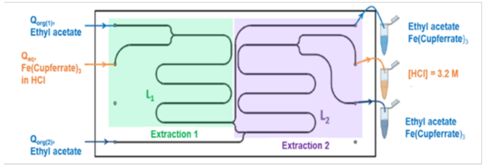
- Development of liquid-liquid micro-extraction
  - Microsystem-based analytical protocol for the extraction and purification of a radionuclide (^{55}Fe) prior to its analysis
    - **Microchannel :** 100 µm width; 40 µm depth; 8, 12, or 20 cm lengths
    - Ethyl acetate as the organic phase,
    - Cupferron in aqueous phase
    - two stage extraction
  - Measurements of Fe extraction yields :
    - 45% in 1 sec in single-stage microsystem (protocol 1)
    - 60% in 1.35 sec in double-stage microsystem (protocol 2)







Single-stage extraction chip



Two-stage extraction chip

S. RASSOU et al 2019 submitted

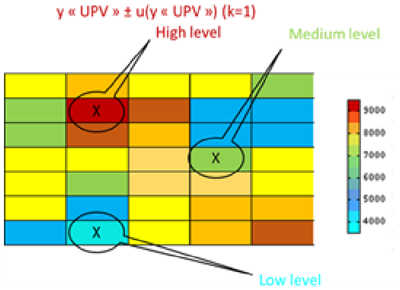
WP6

Performance assessment : statistical approaches

- ❑ Test **the ability of different techniques/methods** (proficiency test) to carry out measurements
- ❑ Estimate **the measurement (in lab or in situ) uncertainty** on synthetic and real samples
- ❑ Try to establish a **complete uncertainty budget** including every step of the INSIDER methodology (geostat & measurement)

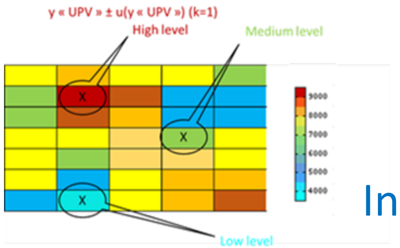
❑ Interlaboratory comparisons organisation on

- ❑ Reference samples : proficiency test
  - ❑ In Lab DA and NDA
  - ❑ Reference materials produced within the project by WP4
- ❑ Real samples : benchmarking
  - ❑ Organize benchmark tests for <u>in situ measurements(NDA)</u>
  - ❑ <u>in lab analysis (DA and NDA)</u>
    - ❑ Homegenised real samples collected



WP6

Performance assessment : statistical approaches



In Lab DA and NDA methods

In situ measurement techniques

ANOVA : ANalysis Of VAriance

Lab i	received sample j	treatment in lab + subsampling	sub sample analysed k	ylab i jkl individual measurement value l	ylabi jk	Ylabi j	u(ylabi j) k=1	ylab i	u (ylab i) k=1
1	sample n°1			Ylab1 111	Ylab1 11	Ylab1 1	u(ylab1 1)	Ylab1	u(ylab1)
				Ylab1 112					
				Ylab1 113					
				Ylab1 121	Ylab1 12				
				Ylab1 122					
				Ylab1 123					
				Ylab1 131	Ylab1 13				
				Ylab1 132					
				Ylab1 133					
	sample n°2			Ylab1 211	Ylab1 21	Ylab1 2	u(ylab1 2)		
				Ylab1 212					
				Ylab1 213					
				Ylab1 221	Ylab1 22				
				Ylab1 222					
				Ylab1 223					
				Ylab1 231	Ylab1 23				
				Ylab1 232					
				Ylab1 233					
2									

ANOVA : ANalysis Of VAriance

- Inter labos
- Inter methods

- Inter samples homogeneity
- Intra method

- In lab treatment (Subsampling)
- Intra sub samples homogeneity

Detection

DOSE RATE				
level	y meas	u (y meas)	y meas meth	y meas meth detection
		k = 1		
same high level location	y "UPV"	u (y"UPV")	y1 "UPV"	y11 "UPV"
				y12 "UPV"
				y13 "UPV"
				y14 "UPV"
				y15 "UPV"
			y2 "UPV"	y21 "UPV"
				y22 "UPV"
				y23 "UPV"
				y24 "UPV"
				y25 "UPV"
			y3 "UPV"	y31 "UPV"
				y32 "UPV"
				y33 "UPV"
				y34 "UPV"
				y35 "UPV"
			y4 "UPV"	y41 "UPV"
				y42 "UPV"
				y43 "UPV"
				y44 "UPV"
				y45 "UPV"
			y5 "UPV"	y51 "UPV"
				y52 "UPV"
				y53 "UPV"
				y54 "UPV"
				y55 "UPV"
	y "SCK"	u (y"SCK")	y1 "SCK"	y11 "SCK"
				y12 "SCK"
				y13 "SCK"
				y14 "SCK"
				y15 "SCK"
			y2 "SCK"	y21 "SCK"
				y22 "SCK"
				y23 "SCK"
				y24 "SCK"
				y25 "SCK"
			y3 "SCK"	y31 "SCK"
				y32 "SCK"
				y33 "SCK"
				y34 "SCK"
				y35 "SCK"
			y4 "SCK"	y41 "SCK"
				y42 "SCK"
				y43 "SCK"
				y44 "SCK"
				y45 "SCK"
			y5 "SCK"	y51 "SCK"
				y52 "SCK"
				y53 "SCK"
				y54 "SCk"
				y55 "SCK"
	...			
idem medium level	...		...	...
idem low level	...		...	...

- Inter institutes
- Inter methods

- Intra institute
- Intra method
- Location precision

- Detection

X

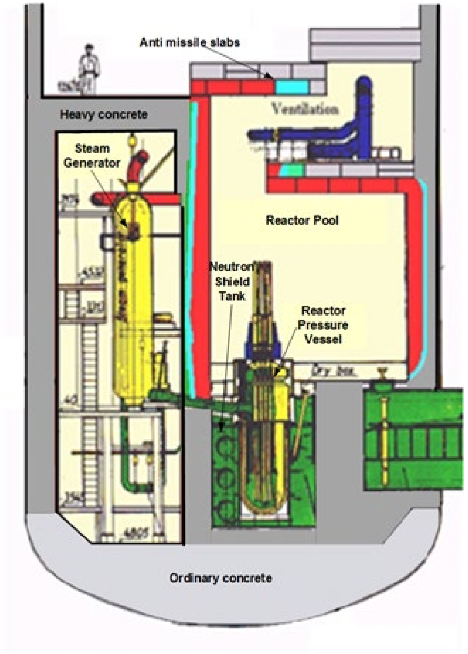
- Inter levels

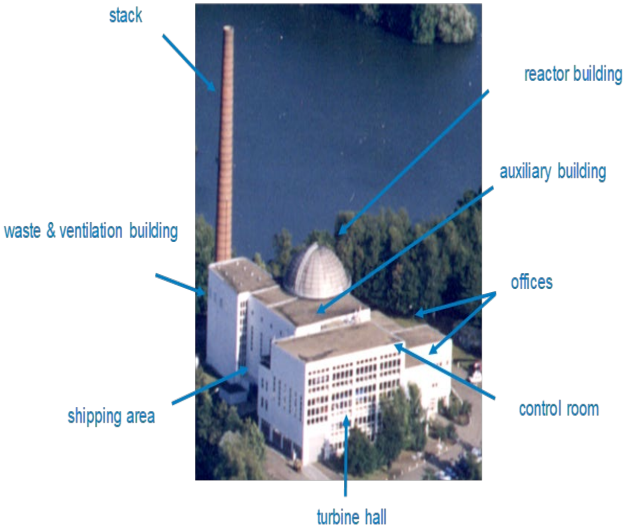
X

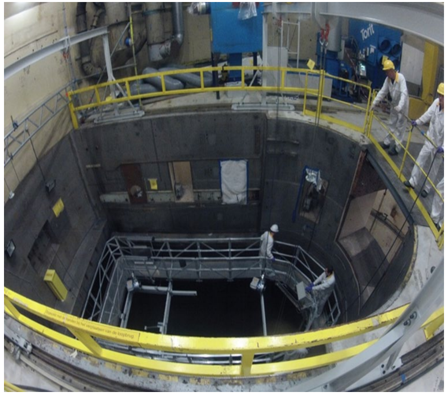
X

On site benchmarking: Use case 2 (NPP)

BR 3 Reactor biological shield







WP5

In situ analysis performance assessment

- in situ analysis :
  - Sampling strategy: interest of small data set
  - Improvement through performance assessment:

measurand = (X ± U) unit

Dose rate

Total gamma

^{133}Ba, ^{152}Eu, ^{154}Eu, ^{60}Co (γ spectro)

Validated analytical method:
Accuracy = Trueness + precision

in situ inter-teams comparisons : 5 different teams

Measurement process:
5 measurements with detector in the **fixed** position
5 measurements with **removing/replacing** detector
= 25 measurements
by detector to source distance
by measurement point

With 2 detector-to-source distances
With 3 measurement points

Detector positioning uncertainty

Detector location uncertainty

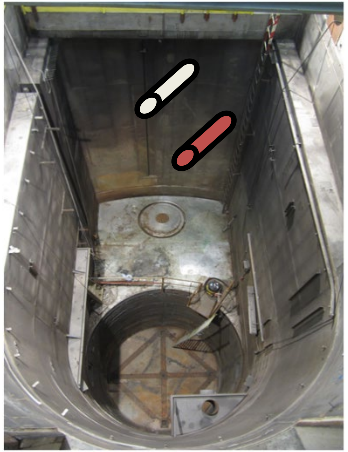
Activity or concentration level uncertainty

WP4 WP6

Interlaboratory comparison contribution

- <u>In lab. analysis</u> :
  - Sampling strategy: reduced number of samples
  - measurand = (X ± U) unit

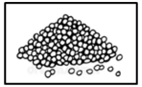
133Ba, 152Eu, 154Eu, 60Co (gamma spectrometry)
total gamma
3H, 14C, 41Ca



Using validated analytical method:
Accuracy = Trueness + precision

WP6

Interlaboratory comparisons on synthetic samples



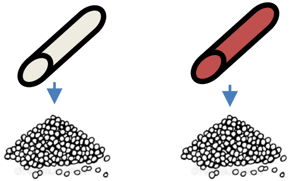
Concrete CRM

Method performance

lab 1
lab 2

WP6

Interlaboratory comparison on real samples



U hom

U hom

lab 1
lab 2

lab 1
lab 2

Measurand

WP2 WP 3 WP5

Future benchmarking on use case 1

WP6

Liquid effluent tank storage at JRC

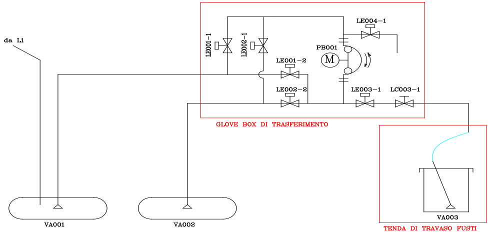
Main RN to measure:

^{14}C, ^{41}Ca, ^{63}Ni, ^{79}Se, ^{90}Sr, ^{93}Zr, ^{99}Tc, ^{107}Pd, ^{147}Pm, ^{151}Sm e ^{241}Pu, ^{55}Fe, ^{59}Ni, ^{93}Mo, ^{129}I, ^{60}Co, ^{94}Nb, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{241}Am, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, $^{239+240}Pu$…

Which measurements?

- ❑ **Dose rate**
- ❑ **Total gamma**
- ❑ **Gamma spectrometry**

- after homogenisation with stirrers in operation
- after deposition of the solid fraction after long stop of the stirrers



In lab analysis on samples

INSIDER project perspectives

- **Innovative metrological study** based on a multidisciplinary network and **D&D key activities**
  - New D&D matrix reference materials development
  - Intercomparisons on real samples and Inter-team
  - Analytical innovation needs identification, development and implementation
  - Correlation and scaling factors: Improvement of accuracy estimation of traces (DTM RN)
  - Advanced integrated approach for site radiological characterisation and automation of characterization process…
  - Decommisionning operating experience

- **Methodological guides** updated according to benchmarking feedback
  - Established link with standardisation commissions (ISO) for future international standards
  - Contribution to European learning (ELINDER)
  - Interface with other EU initiative (SHARE, METRODECOM projects)

- Potential **further opening of the project**
  - Extension/application of the methodology and approaches : historic wastes, graphite reactors…
  - Interface with digital tools: Imaging, virtual and augmented reality

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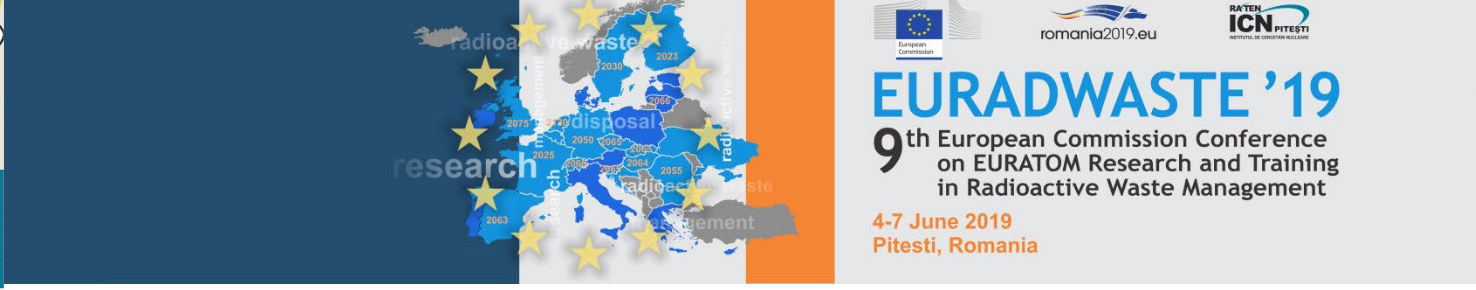

THANK YOU for your attention

Any questions?

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