# THE EUROPEAN R&D PROJECT INSIDER: ACTING ON THE UPSTREAM STAGE

DE LA RECHERCHE À L'INDUSTRIE

CETAMA
Métrologie et Analyses Chimiques


## NKSB-RadWorkshop 2018

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# Context of D&D waste management

## A global international 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 facilites 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…

# About INSIDER

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

- A EU-funded Horizon 2020 project

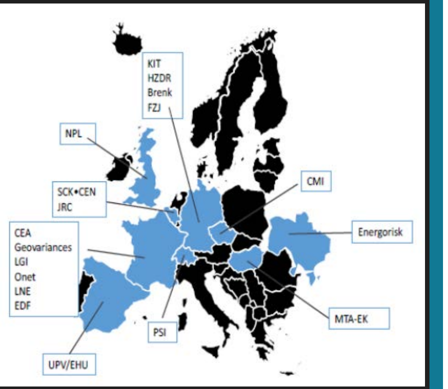
"Research and innovation on the **overall management of radioactive waste other than geological disposal**"
"Management of **non-standard waste** including D&D waste"

- 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**

# A European consortium




- Launched in **June 2017: 4-year project**
- **18 partners** from 10 European countries
- Coordinated by the **CETAMA (CEA Nuclear Energy Division)**

# The CETAMA


CEA Marcoule Center


ATALANTE facility in CEA

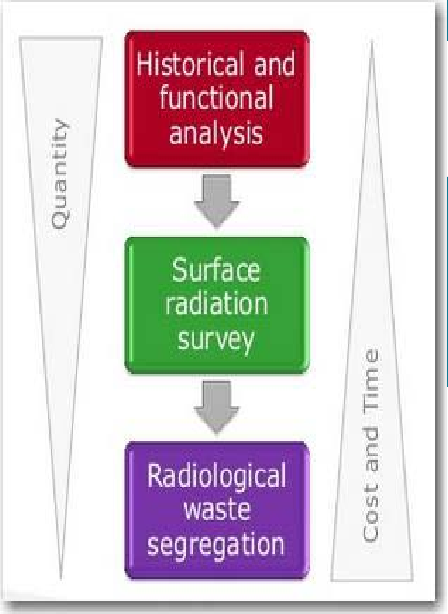

LAMMAN Metrology lab

- 1961: creation of the Commission for the Establishment of Analytical Methods at the CEA by the high commissioner F. Perrin
- Its objective is to carry out actions targeting measurement and analysis result quality improvement in the nuclear field
- It gathers a European network of analytical labs and experts, organised in technical working groups (13):
  - WG 10 sampling and WG 11 statistics
  - WG 14 LLRN analysis (Tc-99,Ni-63, Fe-55)
  - WG 34 Nuclear measurements
- The Tools targeting quality improvement
  - Reference materials fabrication and certification
  - PTS and ILC for method validation organisation
  - Analytical methods and guidelines
  - Support to standardisation
  - Knowledge transfer and valorisation

INSIDER project will maintain a collaborative transversal structure.
To address current and future challenges in the analytical field, meeting both the nuclear industry's and the laboratory's needs

# INSIDER key objectives

## Optimise the sampling strategy under constrained conditions




Selection and development of waste-led statistical approaches

## Assess the performance of avalaible measurement techniques

Selection and evaluation of analytical techniques applied to real D&D cases

Performance assessment of in situ and in lab (DA and NDA) measurement methods on real use cases

## Establish common methodologies to deploy reference guidelines

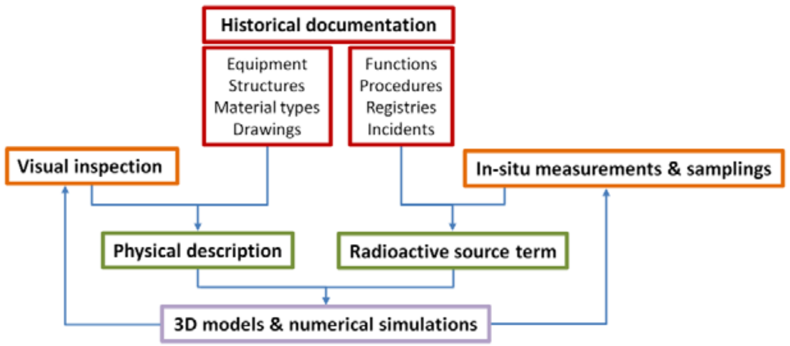
# Three case studies

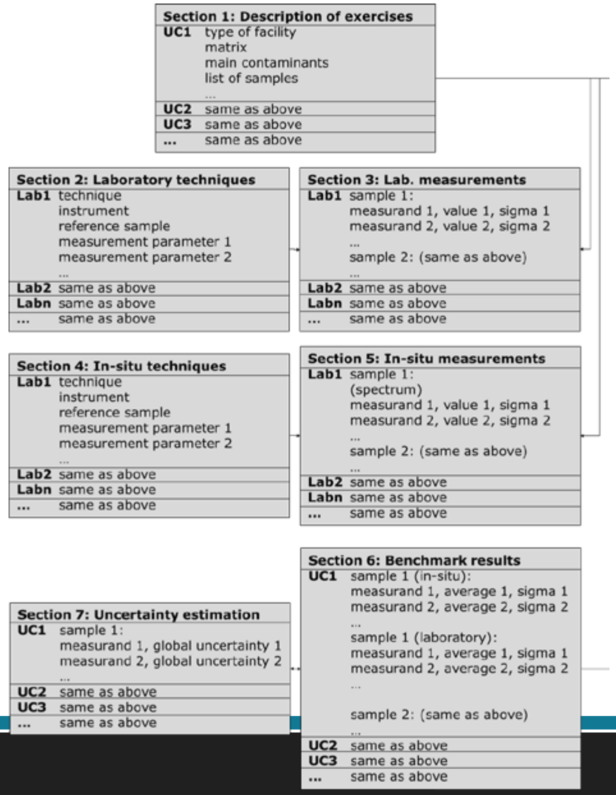
Apply the methodologies to real worksites under decommissioning

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)

# INSIDER approaches and structure

# WP2 - Input data & validation methodology

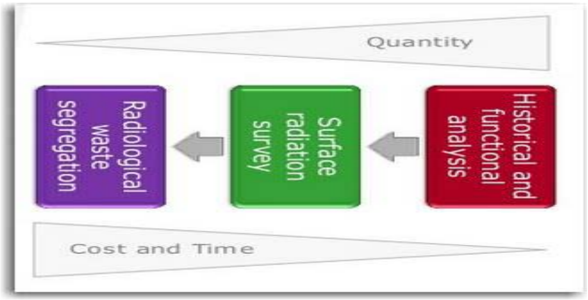


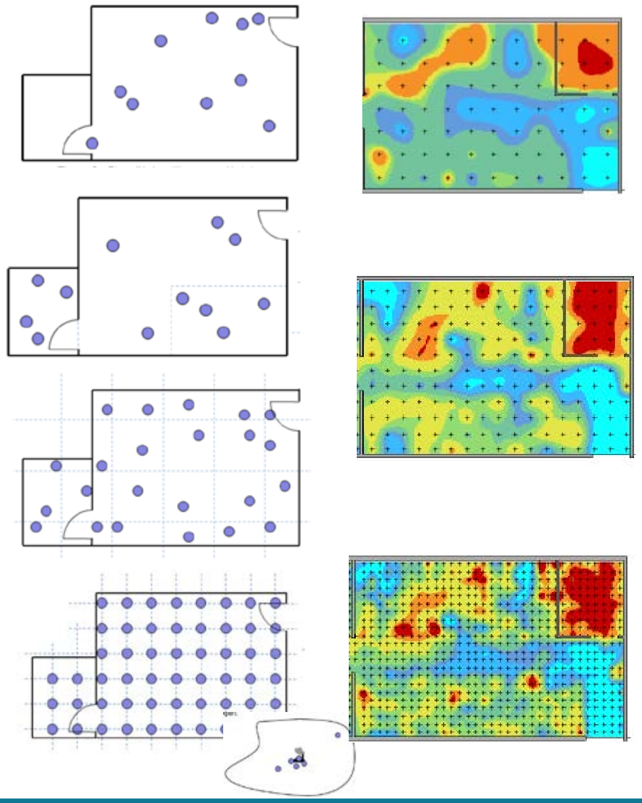




## Objectives

- Identification of operational needs and (regulatory) constraints
  - A review on how characterisation processes are implemented by different end-users, identifying the related regulatory requirements and depicting the major constraints found in the process
- Define objectives for cartography and characterisation
  - Specific objectives for characterisation and cartography and identify key parameters for decommissioning operations orientation & scenario improvement and documentation
- Comparison with the state of the art and identification of technological gaps
  - The need to develop new techniques for sampling and measurement (lab & on-site) based on the analysis of end-user requirements and characterisation objectives
- Organise an experimental benchmark
- Perform economic impact assessment
- Elaborate good practices and guidelines

# WP3 Objectives - State of the art



- Selection of state-of-the-art techniques concerning sampling design optimisation
  - Overview of relevant standards, guides, methods used for sampling design
  - Overview of different sampling design objectives that are being/can be used in the framework of initial nuclear site characterisation
  - Examples of state of the art implementation in the field of initial nuclear site characterisation in view of decommissioning and beyond
  - Potential return of experience from spatial distributions of radiological contamination for the selected test cases
  - Specific focus on constraint environments and therefore statistical approaches based on small data sets

NEEDS

Uncertainty assessments of all techniques
Consistency checks
Lack of guidance focused on the front-end of decommissioning
Lack of integrated approaches

# WP3- Developments

- Statistical approach development and implementation
  - A generic strategy for handling the problem definition, data analysis and sampling design in the field of initial nuclear site characterization has been developed. The strategy includes an overview of commonly used data analysis and sampling design methods, applicable in this field.
  - Gather prior knowledge for each test case (historical assessment + available data from non destructive and destructive analyses).
  - Define statistical plan for each test case leading to a first sampling plan (including sample requirements).
  - Analysing results from first sampling and analyses (including benchmark) potentially leading to a second sampling iteration.
  - Analysing results from second sampling and analyses.

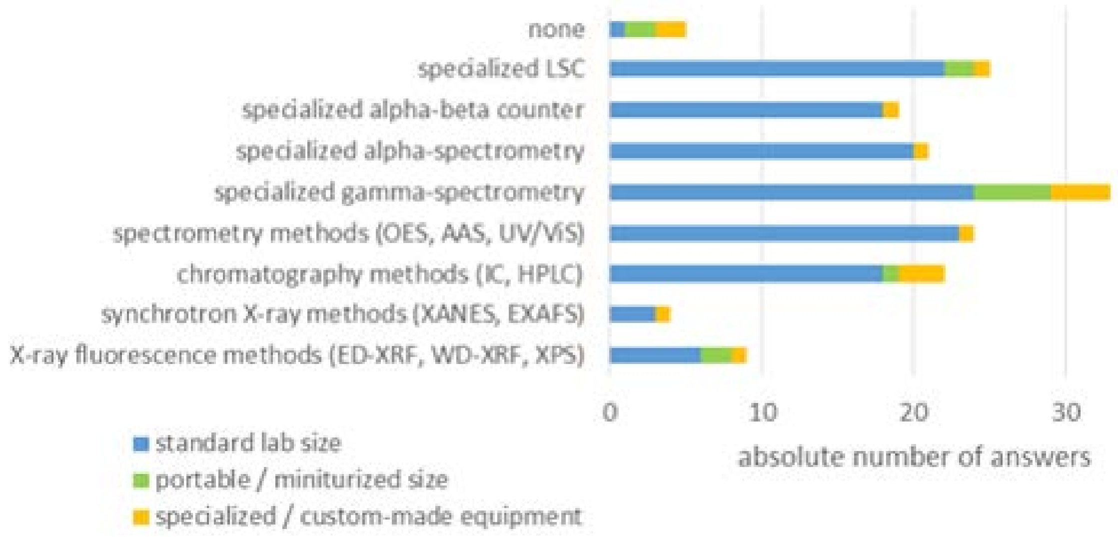
- Testing this approach in the 3 different case studies

- Return of experience from the overall uncertainty calculations

# WP4- Analysis & metrology objectives

## In lab radiochemistry analysis methods state-of-the-art: a survey in Europe

- **More rapid and cost effective analytical methods**
  - Implication of optimising nuclide separation and new development of methods are highest with > 80 % „important“ or „very important“
  - 35 % prioritised miniaturisation/on-site methods
  - Availability of AMS, ICP MS and  TIMS approaches
- **Retaining know-how** and availability of **reference material** (79 %) second in importance




## 1 solid reference materials

Heavy concrete doped with

**Ba-133**, Eu-152, Co-60, Eu-154
H-3, 41-Ca

## 1 liquid reference samples

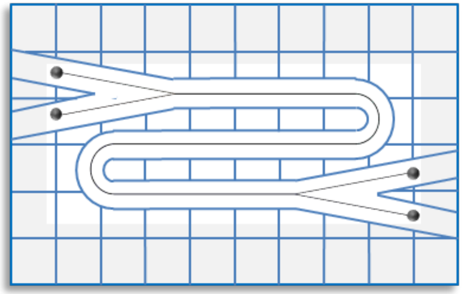
- simulating an effuent solution  (pH)

RN from

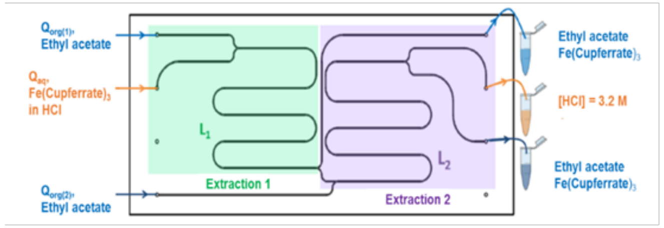
| Main contaminants | Activity concentration range (Bq/g) |
|---|---|
| Ni-63 | 1-10 |
| Sr-90 | 1-100 |
| Pu-238 | 0.1-10 |
| Pu-239 | 0.1-10 |
| Am-241 | 1-10 |
| Co-60 | 0.1-10 |
| Cs-137 | 1-200 |
| Fe-55 | 0.1-5 |
| Pu-241 | 1-50 |
| U-238 | 0.1-10 |

# WP4 - Development

## Microsystem-based analytical protocol for the extraction and purification of a radionuclide ($^{55}Fe$) prior to its analysis



*Single-stage extraction chip*




*Two-stage extraction chip*

**Microchannel :** 100 µm width; 40 µm depth; 8, 12, or 20 cm lengths

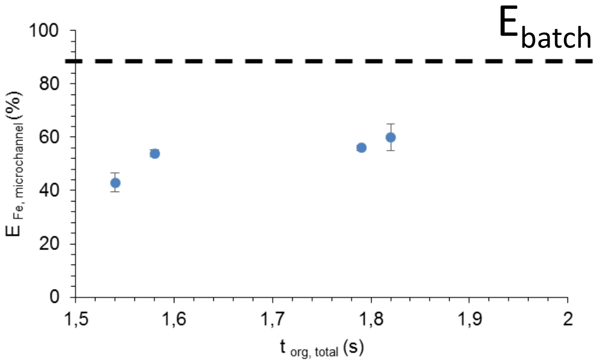
**Development of liquid-liquid micro-extraction**

- using ethyl acetate as the organic phase
- Two-stage extraction with cup ferron initially in the aqueous phase

**Achievement of optimised aqueous and organic phases flow rates** (Q)
to maintain a stable interface and a laminar regime

**Measurements of Fe extraction yields :**

- **45% in 1 sec in single-stage** microsystem
- **60% in 1.35 sec in double-stage** microsystem




*Example of measured extraction yields as a function of time of contact of phases in the microsystem*

*S. RASSOU et al to be published*

# WP5 - In situ measurements

- Identification of different European companies specifying methodologies for radiological characterisation of nuclear installations undergoing decommissioning

**Final Product:** Data-Base of 26 European companies

Working on:

Equipment manufacturing/dist.
Technical expertise
Engineering
Nuclear servicies

- Inventory of the available radiological characterisation methodologies, mainly in the field of gamma-spectrometry, dose rate measurements and radiation imaging (gamma camera), that may be potentially applied in constrained environments in terms of radioactivity (MA-HA), difficult accessibility and/or, underwater interventions.

- In situ $\alpha$ and $\beta$ measurements (HTM)
- Field DA instrumentation

# WP5 - In situ measurements

## On going activities

- Classification and categorisation of the constrained environments as well as the impacts generated by such environments
- Challenges that must be addressed for each of the above constrained environments
- Analysis of the strengths and weaknesses of all the available radiological characterisation methodologies in each constrained environment
- Recommended in situ measurements techniques for each constrained environment
- Investigation on how numerical simulations are able to predict experimentally obtained results
- Proposal of the best practical solution for the three “use cases”

# WP6- Analytical validation:performance assessment

- 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
  - The objective of this ILC is to allow each laboratory to evaluate its performance in comparison with the other participants in order to improve its results.
  - The reference materials RM used in this ILC will be prepared and sent to the participating laboratories by the WP4
  - Estimate the measurement uncertainty for each measurements

- Real samples : benchmarking
  - Participate in selection of real sample(s) (use cases)
  - Organise benchmark tests for in situ measurements and in lab analysis
  - Estimate the measurement uncertainty for each measurements

# WP6 : ILC Contribution

## IN Lab NDA methods

| Lab i | received sample j | ylabi jk | Ylabi j | u(ylabi j) k=1 | ylab i | u (ylab i) k=1 |
|---|---|---|---|---|---|---|
| 1 | sample n°1 | Ylab1 11 | Ylab1 1 | u(ylab1 1) | Ylab1 | u(ylab1) |
| | | Ylab1 12 | | | | |
| | | Ylab1 13 | | | | |
| | sample n°2 | Ylab1 21 | Ylab1 2 | u(ylab1 2) | | |
| | | Ylab1 22 | | | | |
| | | Ylab1 23 | | | | |
| 2 | | | | | | |

ANOVA : ANalys

- Inter sam
homog
- Intr

- Inter labos
- Inter methods

## In situ measurement techniques

ANOVA : ANalysis Of VAriance

| 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" |
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| | | | | y25 "SCK" |
| | | | y3 "SCK" | y31 "SCK" |
| | | | | y32 "SCK" |
| | | | | y33 "SCK" |
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| | | | | 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

X

- Detection

X

X

- Inter levels

# Comparisons - benchmarking and ILC

**Comparisons…**

**… on real samples**
- **In situ NDA (WP5)**
- **In lab DA and NDA (WP4)**

} **For UC1 UC2 UC3**

… on synthetic samples
- In lab DA and NDA (WP4)

} For each CRM (2)

- UC1, liquid effluent tank storage ("tank farm") at JRC, Ispra.
- UC2, biological shield of the BR3 reactor at SCK-CEN, Mol.
- UC3, soil contaminated at CEA site.

For WP6: comparisons on real samples = benchmark

Provisional schedule
(in May 2018)

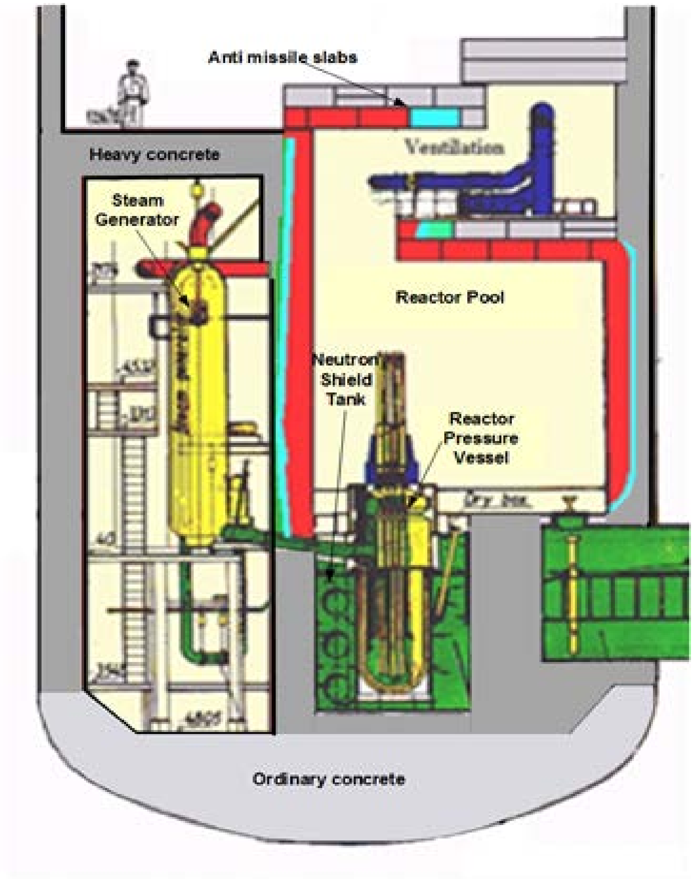
UC1 ⇨ 1st half 2019

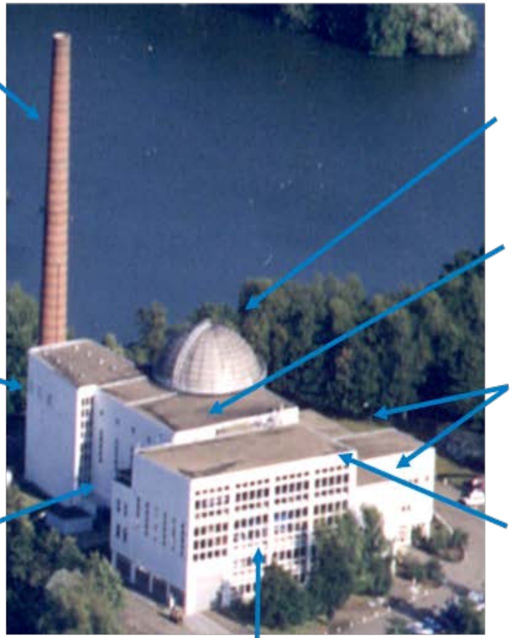
UC2 ⇨ 2nd half 2018

UC3 ⇨ 2nd half 2019

# Use case 2 - Benchmarking

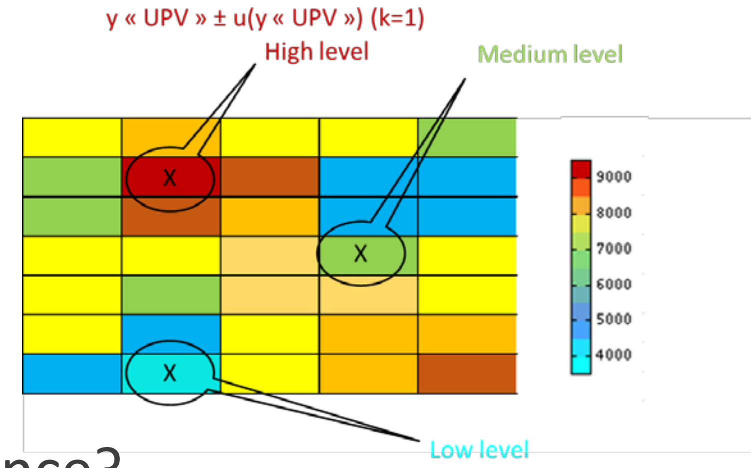
## BR 3 Reactor biological shield




# Use case 2 - In situ measurements

## BR 3 Reactor biological shield




Main RN to measure: $^{133}$Ba, $^{152}$Eu, $^{154}$Eu, $^{60}$Co

**What measures?**

- **Dose rate**
- **Total gamma**

detector-to-source distance?

- in contact
- **at 10 cm ?**

3 measurement points

- **Gamma spectrometry**

detector at the bottom of the pool

in **a fixed and defined position**

Same source

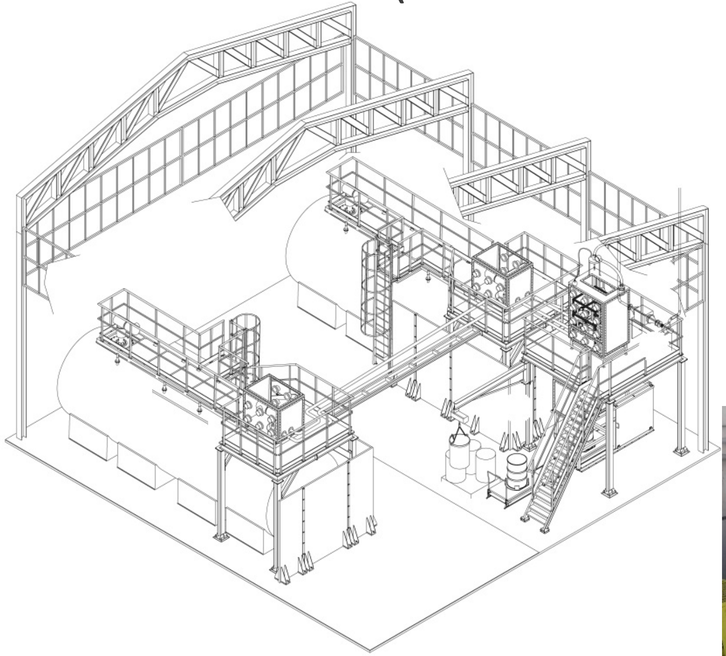
# UC1 - Liquid effluent tank storage at JRC, Ispra

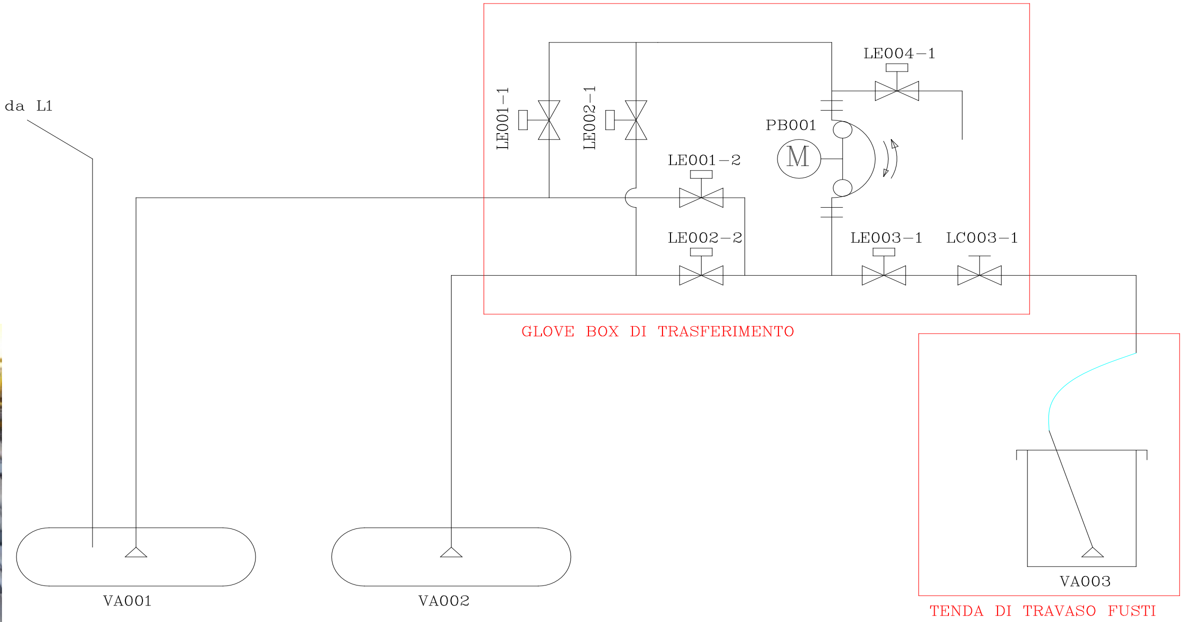
Old liquid effluent treatment station (STRRL).

2 double walled tanks called:

VA001(44.6 $m^3$ of naturally sedimented sludges)

VA002 (37.5 $m^3$ of sludges from more than 200 drums coming from liquid effluent treatment facility).





# UC1- Liquid effluent tank storage at JRC, Ispra

**What measures?**

Activity concentrations range from 0.1 Bq/g to hundreds of Bq/g and are known for a long list of nuclides: $^{14}C$, $^{41}Ca$, $^{63}Ni$, $^{79}Se$, $^{90}Sr$, $^{93}Zr$, $^{99}Tc$, $^{107}Pd$, $^{147}Pm$, $^{151}Sm$ e $^{241}Pu$, $^{55}Fe$, $^{59}Ni$, $^{93}Mo$ e $^{129}I$, $^{60}Co$, $^{94}Nb$, $^{134}Cs$, $^{137}Cs$, $^{152}Eu$, $^{154}Eu$, $^{241}Am$, $^{235}U$, $^{238}U$, $^{237}Np$, $^{238}Pu$, $^{239+240}Pu$.

**In situ measurements (NDA) :** possibility to repeat the in situ measurements in two different configurations:

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

**Goals of the benchmark =>** reproduce the complete radiological characterisation of 1 tank, through both

- In situ measurements from WP5 partners
- samples shipped to analytical laboratories of WP4

# INSIDER - Expected impacts

- ❑ Expected impacts are economic, societal and environmental in the short, medium and long term, **promoting reversibility and sustainability**
- ❑ **Multidisciplinary project:** Analytical lab network and metrology lab support
- ❑ Potential **extension of the methodology**
  - ❑ Historic wastes
  - ❑ Interface with digital tools (virtual and augmented reality)

# Get in touch for more information!

All of the reports produced in the project will be available for download on the INSIDER website: **www.insider-h2020.eu**

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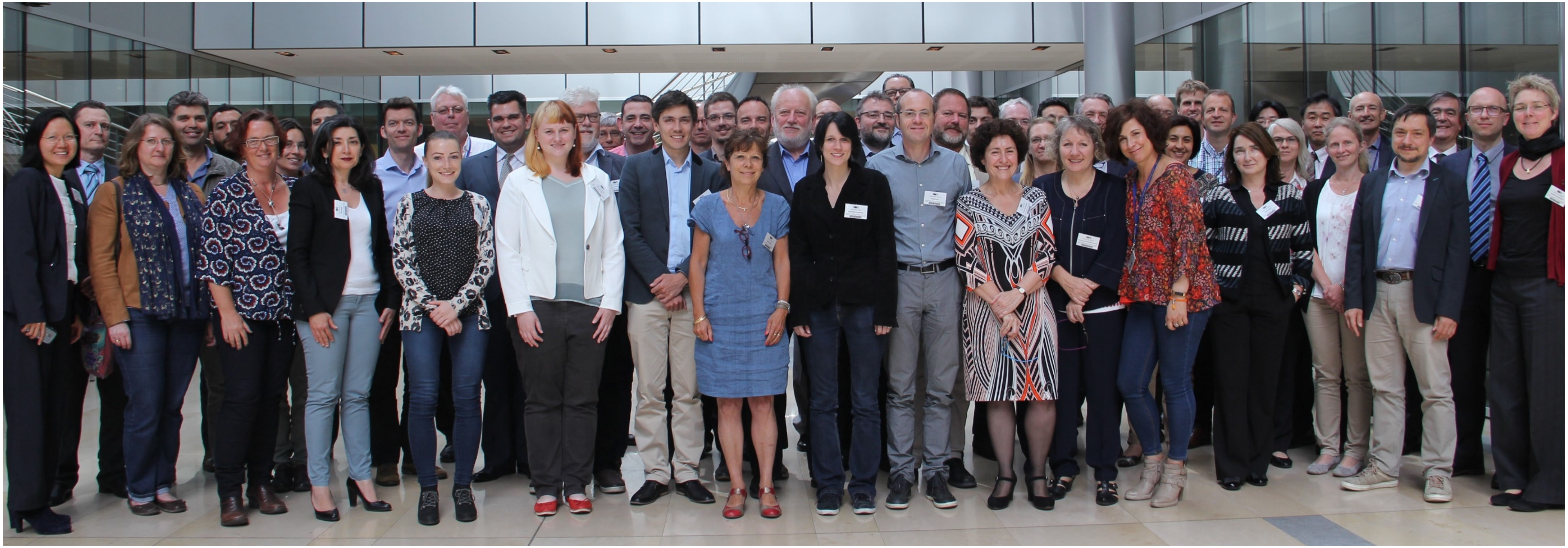

# THANK YOU

INSIDER