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Sampling plans for use case 3

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Summary

This report is dedicated to the sampling strategy for use case 3 (UC3) about contaminated soils, in the context of post-incidental remediation of a site. For this use case, the constraint environment comes from the difficulty to collect samples beneath a building on the one hand and the fact that samples were collected in the past with no possibility for additional samples. However, new measurements (both non-destructive and destructive) are possible on the existing samples, if appropriate and relevant for the overall characterization of this site. This may be performed in order to improve the uncertainty quantification within the INSIDER project at WP6 level (Performance analysis and overall uncertainty), combining outputs from WP3 (sampling strategy), WP4 (In lab analysis) and WP5 (on site measurements).

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Improved Nuclear SIte characterization for waste minimization in DD operations under constrained EnviRonment

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WP3 – Sampling Strategy
Sampling plan for use case 3
Contaminated soils

Deliverable D3.6

Version n° 1.1

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Summary

An integrated and overall approach of pre-decommissioning characterization consists in evaluating historical data, making on-site measurement campaigns, sampling and analysing, developing scaling factors and applying numerical codes. The final objective of work package 3 is to draft a guideline for sampling in the field of initial nuclear site characterisation in constraint environments in view of decommissioning, based on a statistical approach. In order to reach this goal, a first review of available and relevant standards, guides and methods used for sampling design and data analysis has been initially completed. Therefore, statistical approaches to be used in constraint environment have been described as a generic strategy for handling problem definition, data analysis and sampling design definition. This second task has then been implemented in a web-based application presenting the strategy in a more user-friendly way.

Within task 3.3, the strategy will be thoroughly tested in practice within different test cases and the return-of-experience will allow refining it for the final guideline. This task has been initiated by gathering prior knowledge for each test case (historical assessment + available data from non-destructive and destructive analyses) and developing the different sampling plans.

This report is precisely dedicated to the sampling strategy for use case 3 (UC3) about contaminated soils, in the context of post-incidental remediation of a site. For this use case, the constraint environment comes from the difficulty to collect samples beneath a building on the one hand and the fact that samples were collected in the past with no possibility for additional samples. However, new measurements (both non-destructive and destructive) are possible on the existing samples, if appropriate and relevant for the overall characterization of this site. This may be performed in order to improve the uncertainty quantification within the INSIDER project at WP6 level (Performance analysis and overall uncertainty), combining outputs from WP3 (sampling strategy), WP4 (In lab analysis) and WP5 (on site measurements).

1 Introduction and use case context

The EURATOM work programme project INSIDER (Improved Nuclear SIte characterization for waste minimization in Decommissioning under constrained EnviRonment) was launched in June 2017. It aims at improving the management of contaminated materials arising from decommissioning and dismantling (D&D) operations by proposing an integrated methodology of characterization. The methodology is based on advanced statistical processing and modelling, coupled with adapted and innovative analytical and measurement methods, in line with sustainability and economic objectives. The overall objective of INSIDER is to develop and validate a new and improved integrated characterisation methodology and strategy during the D&D process, based on three main use cases – a nuclear R&D facility, a nuclear power plant and a post incidental site remediation.

The main objective of Work Package 3 (WP3) within the INSIDER project, is to draft a sampling guide for initial nuclear site characterization in constraint environments before decommissioning, based on a statistical approach. This is done by selecting state-of-the-art techniques concerning sampling design optimization, using prior information and multiple iterations, testing the approach through different case studies and reviewing the feedback from overall uncertainty calculations. The process followed to meet the main WP3 objective consists of four steps:

1. Status: provide an overview of the available sampling design methods and state-of-the-art statistical techniques.
2. Development: develop a strategy/methodology and implement it in a software package by making use of (and possibly extending) state-of-the-art techniques.
3. Implementation: apply the methodology to the different test cases considered in order to test its adequacy.
4. Guidance: summarize all the findings in a comprehensive sampling strategy guide.

This document is then connected to step number three; the implementation. The strategy developed in step 2 is being implemented on the radiological characterisation of contaminated soils, defined as use case 3 in the INSIDER project. This document hence defines the sampling plan for this post-incidental remediation case. One particularity of this use case is the dataset has been already collected and it is not forecasted to go back on the field for different reasons presented hereafter, in order to collect new samples. However, drill cores are available for additional in situ measurements as well as new samples for laboratory analyses.

2 Characterization objectives

2.1 Global estimation of statistical quantities

For the preparation and management of a soil remediation project, some global quantities need to be estimated in a sound way. For instance, average activity concentration value for the whole area (as well as its related uncertainty) is an interesting parameter and needs to be statistically estimated. The different statistical tests and inequalities can be derived if the dataset is compatible with the underlying hypotheses. Spatial and/or statistical biases need to be carefully addressed. Consequently, the total activity (still along with its confidence level) can be estimated as an accumulation (knowing the total volume and the matrix density).

Other global statistical quantities are linked to specific values. At that stage, global estimations of volumes exceeding radiological thresholds significantly help for the classification according to the different waste categories.

2.2 3D distribution map of activity concentration and waste segregation

In addition to the global estimates presented previously, some local estimates are very relevant for the adequate management of remediation projects. The analysis of depth profiles combined with the horizontal distribution leads to 2D/3D representations depending on the dataset spatial organization. Appropriate geostatistical method need to be carefully selected given the spatial continuity of the phenomenon and the database configuration (linearity, stationarity, multivariate, trend…).

In addition to global estimates, local estimates are expected in comparison to specific radiological values. The local probability of exceeding a radiological threshold then leads to the volumes to be excavated in the different waste categories. At that stage, radiological thresholds for the different waste categories are not fully defined, in particular for and site release values (output of operator impact assessment study). For the segregation between Very-Low Level waste and Low-Level waste, ANDRA specifications are quite clear and require a weighted sum calculation according to scaling factor and nuclide class (IRAS). In any case you will need to have/apply a certain radionuclide vector (including uncertainties) have to be determined and applied as well. Those aspects will definitely need a lot of attention in the coming analysis.

This classification decision can also take the remediation support into account (e.g. averaging out over 1 m^3 or 1 ton or other values). All classification decisions then require working on estimation uncertainties.

Finally, the different costs for the soil excavation, waste confection and disposal may be integrated as a forecast of the remediation project and compared and balanced to the initial characterization costs.

3 Pre-existing data

3.1 Plans and historical knowledge

For some confidentiality reasons the strict minimum of the site context information has been made available within the INSIDER project. However, this situation is sometimes representative of real circumstances for old facilities for instance, for which historical knowledge results are very limited. What can be mentioned is this nuclear facility was devoted to radiochemistry on trans-uranium elements. It was under operation until 1992 on a CEA site in France. The contaminated soil area is located beneath this building, just below a former tank room.

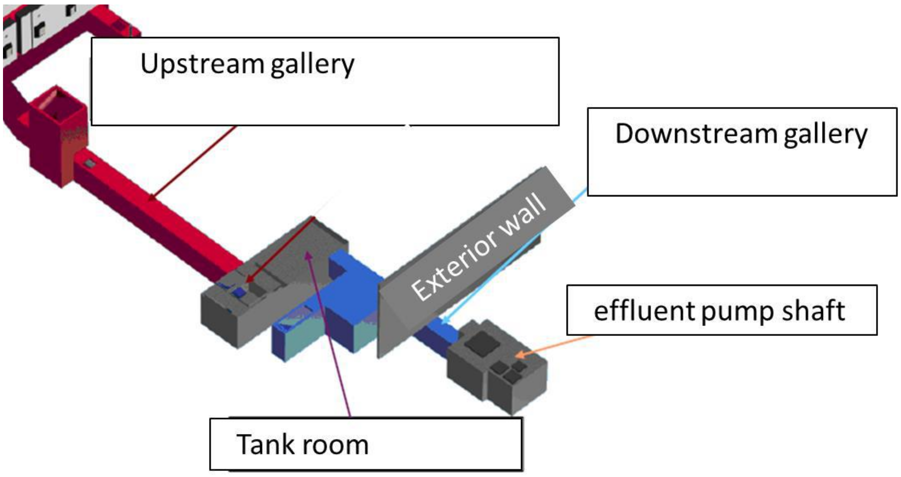

Figure 1: Use case 3 location below a tank room of a former nuclear facility.

It has been reported that different incidents occurred during nuclear facility operation. Contamination of soils beneath the tank room with few TBq of various alpha et beta emitters is expected due to:

- Leaks of radioactive very high active effluent in the tank room
- Several potential contamination pathways to reach the soils such as ingress, cracks or expansion joints of the concrete slab…

3.2 Several horizontal drilling campaigns

In order to improve the radiological assessment of soils below this tank room, different sampling campaigns have been conducted. They consist in 7 horizontal drill holes between 2012 and 2015.

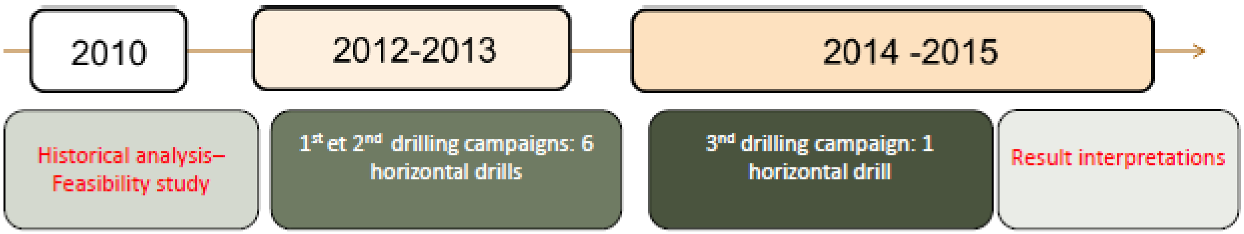

Figure 2: General characterization steps for UC3.

As presented on the vertical and horizontal section views on Figure 3, the 7 drill holes are distributed in two horizontal layers at 0,5 and 1,5 m below bottom of the tank room slab. The drilling machine was located at the bottom of a circular pit outside of the building to access this area and go horizontally. This approach is not very common for soil sampling as generally vertical drill holes from the top surface is preferred. However, due to the presence of the building and the impossibility to introduce the drilling machine (cf. Figure 4) in the tank room, this deported and long-range horizontal drilling location has been preferred.

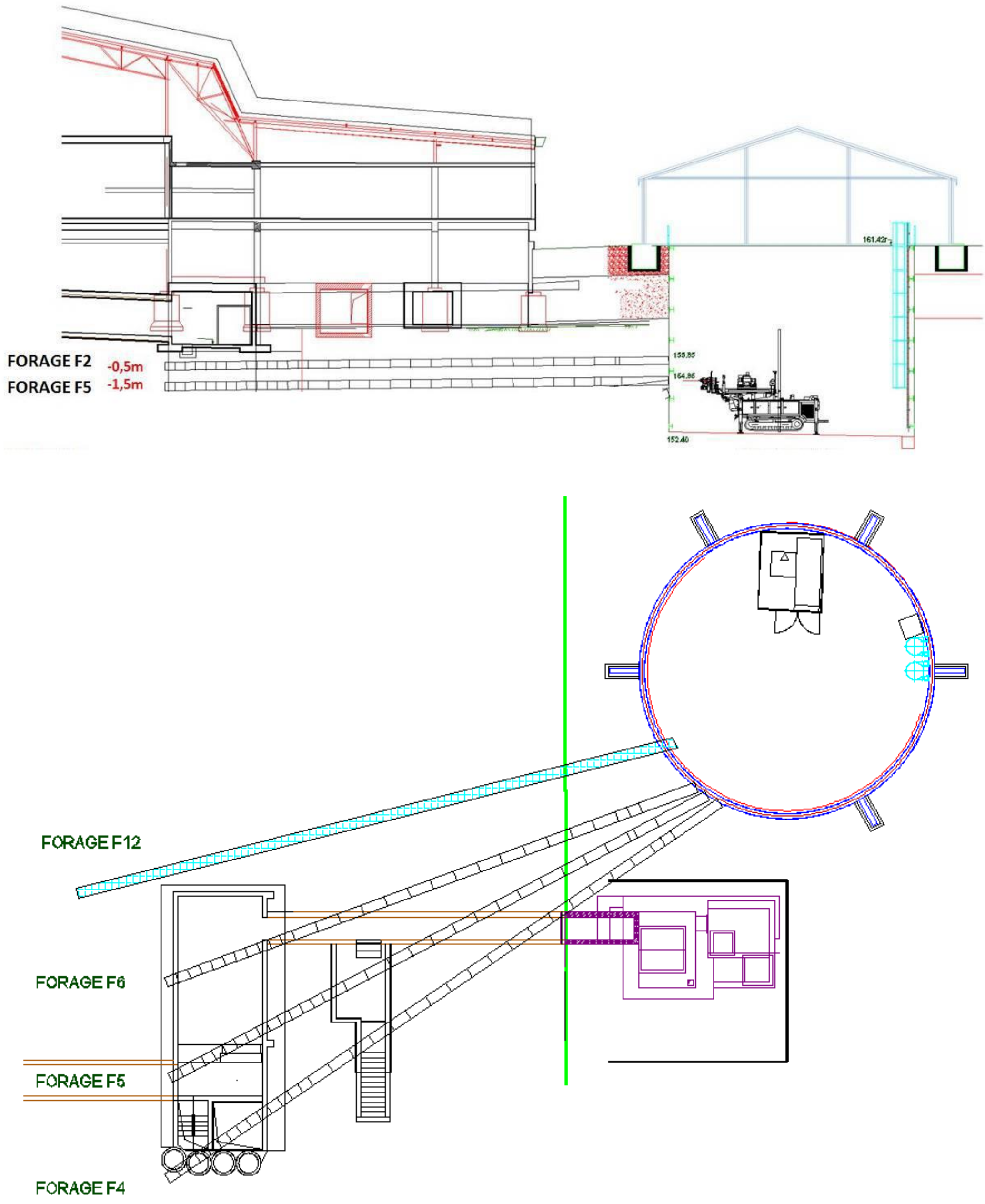

**Figure 3: Vertical cross section (top) of the horizontal drilling layers.
Top view (bottom) of the angular distribution of drill holes.**

Samples have been collected using a sonic drilling method that uses high frequency vibration transmitted to the ground via the drill stem and corer. Soil becomes loose or fluid over a very limited area (1 to 5 mm). The main advantage is the rotating corer penetrates soil easily and quickly.

Figure 4: Sonic drilling machine similar to the one used on UC3.

As for sampling protocol (cf. Figure 5), it consists in

- Lowering (or pushing) the corer at the sampling depth (distance)
- Retrieving up the corer containing the soil
- Introducing the tube to the depth previously drilled
- Recovering scraps with worm screw
- Repeating these steps until the end of the drilling

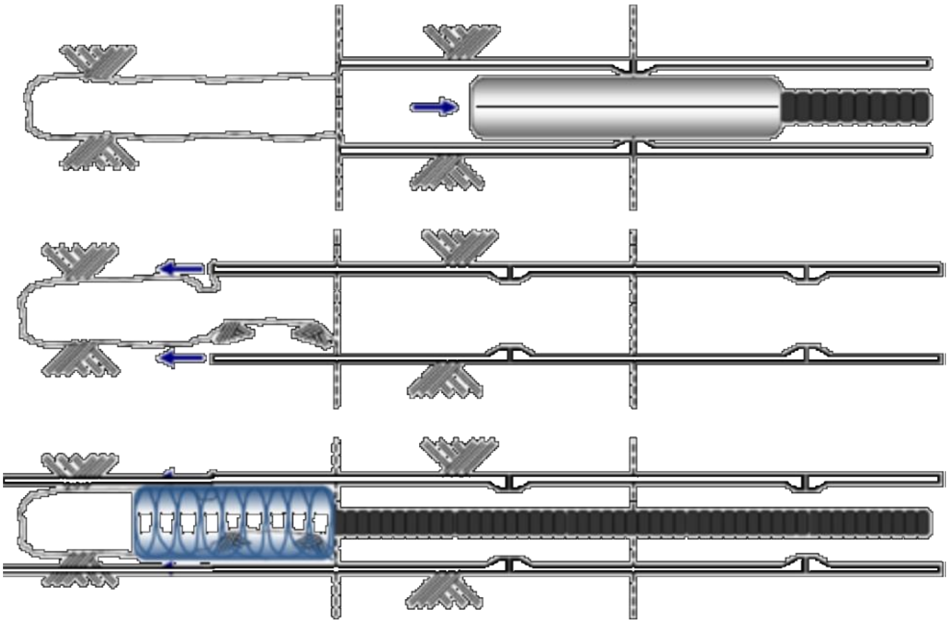

Figure 5: Different steps for drilling samples.

Collected soil proved to be quite homogeneous but with the presence of small to intermediate size gravel in a sandy matrix (Figure 6). Samples have been then constituted taking 500 to 800 g mass (geometry standardized at 500 mL) assuming two core lengths: 0,5 or 1 m. First observations of radioactivity distribution depend on soil compositions and radionuclides chemical properties. In addition, activity is concentrated in small soil particles.

Figure 6: Raw drilling core (top) and result of size segregation (bottom).

3.3 Preliminary analysis of the dataset

Looking to the spatial organisation, samples were collected along 7 cores, distributed in two layers. The sampling resolution is 1 m and is refined to 50 cm in the interest area (Figure 7). Therefore, the first 10-15 meters from the origin point can be considered as an accessibility distance. The last borehole (named F12) is different as it presents a 50 cm sampling resolution from the beginning.

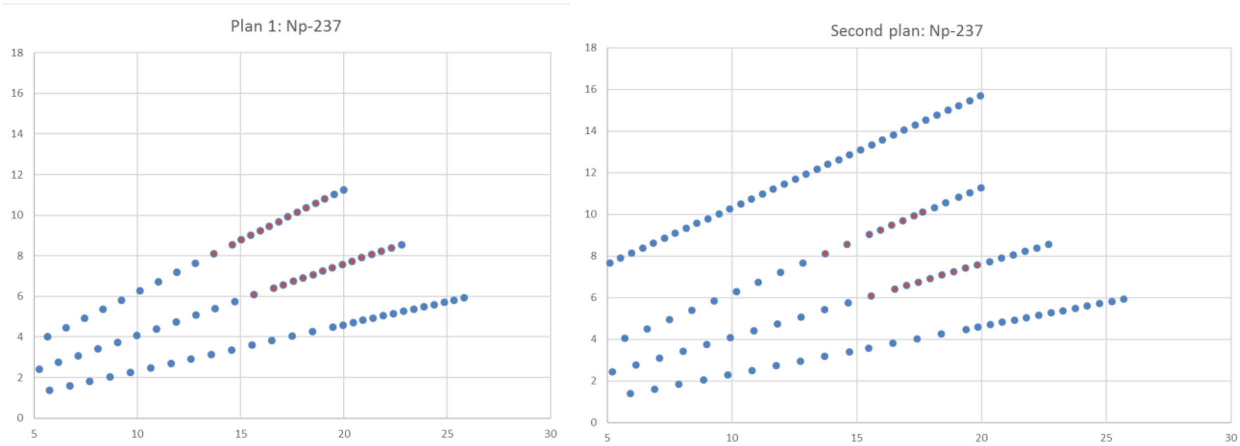

Figure 7: Base maps of the two sampled layers.

The total number of analysed samples then reaches 220, which can be considered as a large dataset at first glance.

Preliminary direct measurements have been performed along the cores. They consist in gamma and X scanning (gross counting) on a regular 5 cm mesh. These indirect measurements probably serve as a semi-quantitative characterisation of the gamma content of soil samples. However, these measurements are not part of the transmitted data but the operator is currently considering adding them to the use case. That would be very relevant for INSIDER project to be able to combine in-situ and destructive values in order to improve the estimations (and reduce the uncertainties).

Main nuclides for laboratory analyses are Np-237, Pa-233 for gamma emitters and Sr-90 for beta emitter. Other gamma emitters such as Co-60, Eu-152, Uranium and Thorium chains are not present (or at very low levels, close to detection limits). Cs-137 and Am-241 are detected on some samples. In addition, the different Plutonium isotopes (238, 239+240 and 241) have been quantified using appropriate alpha measurements.

It seems that alpha spectrometry (dissolution, extraction, electrodeposition) and beta counting (liquid scintillation with a detection limit of 30 Bq/kg) have been initially decided on the basis of the higher dose rate location on the core. At the end, most of all samples have been measured for alpha emitters and only the first layer of boreholes (3 out of 7) for Sr-90.

4 Sampling design

4.1 Dealing with a unique existing dataset

As there is no possibility for new samples and new in situ measurements, the existing dataset is considered as the final one within the INSIDER project for this use case 3. However, non-destructive measurements and new samples can be performed on the existing cores.

There is no sampling design definition as for the other use cases, but the statistical analysis promises to bring interesting and relevant conclusions for the whole INSIDER project due to the number of available samples. Global and local estimates will be calculated as described in § 2.

In addition, sensitivity to dataset extension will be studied as 2 zones can be identified: the inner area with the highest activity levels (corresponding to the 50 cm sampling resolution along the cores) and the accessibility area (with a 1 m mesh). Statistical outputs will differ because of this spatial delineation.

As it seems to be a relevant 3D contamination, areas with high estimation uncertainties as well as extrapolation areas will finally be identified. They would have been used for recommendations of new samples in the case of a site with possible additional investigation.

4.2 Sensitivity analysis by data reduction

Despite the dataset limitations for the definition of the sampling plan as described before, the large number of samples enables a sound sensitivity analysis. Sub-dataset will be extracted from the full dataset in order to quantify the impact on the estimates and their related uncertainties. Different possibilities can be imagined:

- Reduction of sample number per drill hole.
- Reduction of drill hole number.
- Integrating correlation between nuclides by reducing some laboratory analyses.

This approach will definitely provide interesting outputs for the INSIDER project.

5 References

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