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

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UC1 sampling plan, liquid waste storage tanks, JRC Ispra

Deliverable D3.4

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Summary

The objective of INSIDER work package 3 (WP 3) is to draft a sampling guide for initial nuclear site characterization in constrained environments, based on a statistical approach. In this paper, deliverable 3.4 (D 3.4) is presented for WP 3, where the strategy developed in deliverables 3.1 (D 3.1) to 3.3 (D 3.3) is applied to three reference use cases representative of existing decommissioning scenarios.

The present discussion focuses on use case 1 (UC1): the liquid waste storage facility at the JRC site of Ispra (Italy). The proposed characterization strategy developed in D 3.2 is applied in a step by step approach to analyse the pre-existing information (obtained through the use of a pre-sampling questionnaire), and to utilise the available inputs towards the development of sampling plan sufficient for allowing radiological characterization.

1 Introduction

1.1 Background

The facility selected for the case study UC1 is the liquid waste storage facility at the JRC site of Ispra (Italy), referred to as "tank farm" (Figure 1). This is a building commissioned in 2010, de-signed to collect all remaining liquid waste present on site, mostly stored in tanks in the old liquid effluent treatment station (STRRL), to be routed for cementation or other solidification and conditioning treatment. Most of the liquid waste or sludge is contained in two double walled tanks, 12 mm total wall thickness (stainless steel), called VA001 and VA002. A small lead-shielded tank for ILW was added to the storage facility a couple of years later. The latter is explicitly excluded from the sampling plan to be established for this exercise, but may contribute to the overall dose rate in the building.

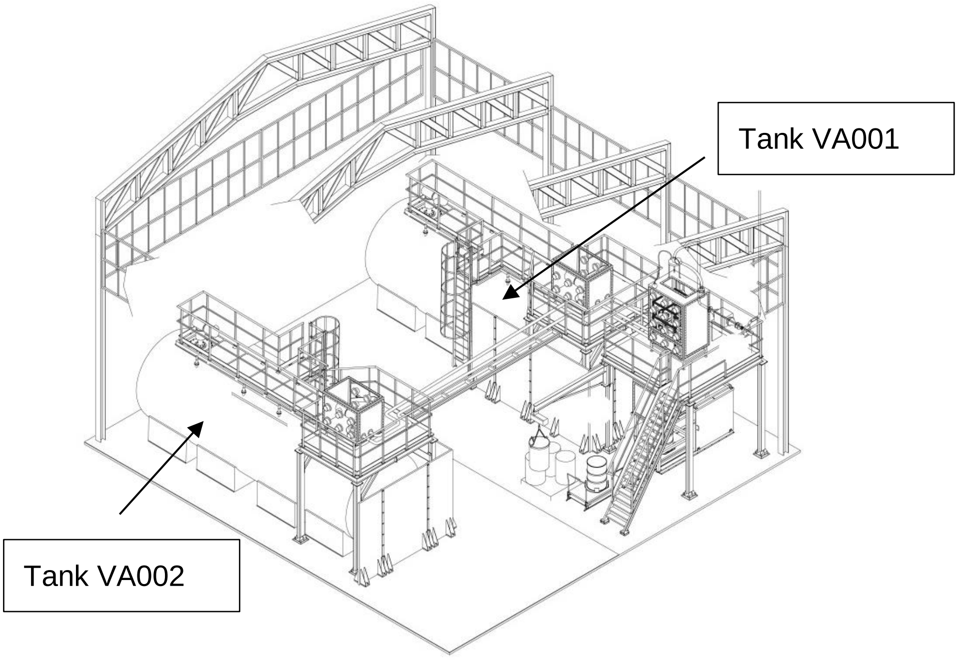

Figure 1: Schematic of tank farm building

The exercise is designed to build upon the sampling strategy developed for the project Improved Nuclear SIte characterization for waste minimization in DD operations under constrained EnviRonment (INSIDER), see Rogiers B. et al (2018). Information for the benchmarking of the use case concept was provided by Peerani P. et al (2017).

1.2 Pre-characterisation questionnaire

A pre-characterisation questionnaire was used to determine the historical background, scope, purpose and end points of the characterisation. This was sent to the Ispra team for completion and information gathering.

The completed questionnaire is attached in the Appendix.

From the completed questionnaire and preliminary data provided, some information is available to support in the preparation of the sampling plan:

- The historical origin of the waste is the operation of a nuclear research facility including a nuclear research reactor. No end date and further specifics of the research facility are provided.
- The stated objective of the sampling plan is to classify and characterise the waste in view of conditioning and management of the waste for storage and/or disposal, and to obtain a better understanding of the radiological safety implications of storing and processing the waste.
- Apart from one sampling campaign during which the chemical and radiological properties of the tank contents were measured in 2013, no additional data from environmental or radiological surveillance relating to the waste is available.
- A stated uncertainty relates to the relative inhomogeneity of distribution of radionuclides in the waste.
- Material data safety sheets about the waste do not exist, in particular no indication of the chemical toxicity is present.
- According to the pre-sampling questionnaire, two sets of scaling factors are available, but these have not been provided together with the sampling reports: it is a stated intent of this exercise to come up with scaling factors (if any) which are not prejudiced by way of information supplied in advance.
- The maximum dose rate on contact of the tanks is recorded as 30 µSv/h as a maximum. It is not clear which of the two tanks is associated with the maximum dose rate.
- Accessibility of the waste in the tanks for laboratory sampling is limited to in-stream sampling while pumping contents from the tanks or through a sampling loop.
- External access to the tanks for dose rate measurements is possible in general but is restricted because of the location of the tanks against the building walls, and by a shielding wall covering part of one tank (see Figure 2).
- Surface contamination is not expected to be an issue here as the waste is contained within the tanks. The absence of surface contamination is stated as part of the information provided.

Figure 2: View of tank with shielding wall covering half of side of the tank

2 Objectives

2.1 Main objective

The objective for the campaign should be part of the initial request for characterization. In the context of this exercise, the initial request is considered to be included in the responses to the pre-characterization questionnaire (see Appendix), as described in Section 1.2 above.

The main objective here is to fulfil the necessary requirements for conditioning and removing the waste according to the relevant waste acceptance and possibly disposal criteria.

It is noted that relevant waste acceptance criteria for this waste have not yet been determined by the relevant Authority, and applicable clearance or acceptance limits are therefore not known. The intended treatment or conditioning strategy is still in the process of being defined; while cementation has been investigated as a possibility, this has yet to be confirmed.

Given this background, the primary objective for this campaign is to characterize the waste as exactly as possible, both in relation to its physico-chemical properties as well as to its radiological content.

Activities required in order to reach the main objective could be summarised as follows:

- Determine physical and chemical properties of the waste, and
- Determine radiological properties of the waste:
    - dose rate in the working area,
    - degree of homogeneity/spatial distribution,
    - nuclide inventory and quantification, and
    - waste classification.

2.2 Highest priority objective

Given the pre-existing knowledge about the waste, including the pre-existing laboratory data with comprehensive analysis of physico-chemical parameters, the radiological characterisation of the waste here is the highest priority objective, i.e. determination of

- type, isotopic composition and volumetric distribution of radioactive waste in waste containers (tanks) and
- difficult-to-measure (DTM) nuclides and their correlations or scaling factors to easy-to-measure nuclides.

2.3 Statistical indicators

If a uniform distribution of data is expected, an unbiased survey is the preferred sampling method, and vice versa, if the distribution is expected to be non-uniform, a biased survey is the better option.

The validity and usefulness of scaling factors must be determined, using as a starting point the pre-existing data as an input. While preliminary scaling factors for specific process streams at Ispra have been determined in the past, these have not been provided so as not to prejudice the analysis of the pre-existing data.

3 Constraints

3.1 Access for sampling

According to the information provided on the tanks, access for non-destructive in-situ dose rate measurements and in-situ gamma spectrometry is limited due to the presence of a shielding wall and due to the location of the tanks against the building walls and on the floor of the building.

In addition, destructive sampling of the sludge in the tanks is restricted to transfers of contents from the tanks to a temporary storage container, or to sampling in-stream while pumping the tank contents through a loop, via a bag-in bag-out glove box arrangement.

It is noted that the historical origin of the two tanks' contents is not the same, and that mixing between the tanks does not take place. The two tanks are therefore to be characterized as separate entities.

3.2 Homogenisation of tank contents

Both tanks are equipped with stirrers to ensure homogeneity of the contents. It can therefore be expected that measurements before and after stirring events will yield different outcomes. Notwithstanding the option of stirring tank contents, deposition of solids at the tank bottom may have occurred that is not possible to mobilise through stirring, leading to a layered structure of the radioactive waste in the tanks.

3.3 Reference samples

As stated in the benchmarking design by Peerani et al (2017), one of the major problems in characterising tanks containing sludge (mixed liquid/solid) is the unavailability of suitable reference samples with adequate solid fraction.

4 Pre-existing data

4.1 Historical information

According to the Ispra brochure (see European Commission (2016)) and additional information provided, the liquid waste to be characterized at the tank farm derives from decommissioning processes during the decommissioning of research & development projects at the research reactor. The waste consists of two tanks, each about 50 m^3 in volume, of LLW sludge with activities up to a little over 100 Bq/g, and stemming from the liquid effluent treatment facility.

According to the information supplied, there is no contamination in the building; hence surface contamination measurements are not required. The maximum dose rate on contact on the tanks is reported to be 30 µSv/h. It is supposed that radiation from the ILW liquid tank located in the same building is not contributing significantly to the dose rate at the surface of tanks VA001 and VA002.

It is noted that the pre-existing samples were drawn immediately following the filling of the two tanks, and after stirring the contents. Consequently, water content of the samples is high as there has been no separation of solids within the tank contents. It is noted further that in the meantime, deposition from the sludge may have occurred on the tank bottoms, as evidenced by taking gamma dose rate readings from the tank exteriors. Further sampling at the present stage is therefore likely to result in deviations from the data found during the first sampling campaign.

4.2 Data collected

A set of sludge samples was collected in the years 2012/2013; a first set consisting of 12 sludge samples from tank VA002 (referred to as WP 03, see Londyn P., (2013a)), and a second set of 12 sludge samples from tank VA001 (labelled WP 04, see Londyn P., (2013b)). Two analysis reports are available dated February and April 2013.

The 12 sludge samples for tank VA001, 600-700 ml in volume each, were collected in 750 ml bottles. Analysis results are available for these for chemical characteristics and elemental composition, granunolometry of solids, thermogravimetry and radiological content:

- For the determination of elemental composition, sludge samples (20 ml each with HF) were converted into solution using microwaves assisted digestion, diluted 1:100 and analysed using ICP-MS (elements Na, Mg, Al, K, Ca, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Sr, Zr, Mo, Cd, Sb, Ba, Pb, Hg, Th, U) or 7 ml- samples were converted into solution using microwave assisted digestion, diluted 1:10 and analysed using ICP-MS (elements Li, B, Si, S).

- For the determination of the granulometry of solids, each bottle with a sample-suspension was thoroughly hand-shaken. For the Static Light Scattering measurements, the tip of the pipette was dipped in a midheight of the suspension and 1-ml volume of the sample was pipetted in an Eppendorf tube. In order to split agglomerates and remove gas, the Eppendorf tube was sonicated for 2 minutes. After sonication, 150 µl of the suspension was pipetted in a magnetic stirred measuring "fraction cell" containing 9850 µl of degassed MilliQ water (dilution factor of 0.015). Analysis was done by laser scattering particle size distribution analyser. Vigorous stirring prevented the particles from sedimentation in the fraction cell (after the measurements, no sediments were found on the bottom of the cell). For scanning electron-microscopy measurements, the tip of the pipette was dipped in a mid-height of the suspension; a withdrawn drop of a sample was put on a stub with a carbon-conductive tab and dried. Consequently, the dried sample was Pt/Pd-coated.
- For the determination of thermogravimetry, samples (ca. 10 g) were obtained as black suspensions in water. Samples were transferred to 25 ml beakers and were slowly dried in an oven at 90 °C for 72 hours to evaporate all water and obtain grey powders. Before thermal analysis measurements, the samples were kept for 24 hours in a desiccator under dry air. The desiccator was filled with KOH pellets.
- Chemical analysis of sludge samples included determination of pH, water content, bulk density, conductivity, determination of total solid, total dissolved solid and total suspended solid, determination of total carbon (TC) and total organic carbon (TOC), determination of phosphates and total phosphorus, determination of ammonium content and determination of cationic, anionic and non-ionic surfactants.
- Radiological analysis of sludge samples was performed using liquid scintillation counting (LSC), gamma spectroscopy (GS), low energy gamma spectroscopy (LEGS) or alpha spectroscopy (AS). For this, a sub-aliquot of approximately one to ten grams was sampled from the original stirred samples, leached with mineral acids and the resulting leachates analysed for the determination of alfa, beta and gamma emitters.

For tank VA002, there was a similar sample set of 12 sludge samples analysed. Only the results for chemical analysis and for radiological analysis are available for these samples.

5 Preliminary data analysis

5.1 Pre-processing

Removed from public version.

5.2 Exploratory data analysis

Removed from public version.

5.3 Data analysis

Removed from public version.

5.4 Post-processing

Inspection of the pre-existing data allows the following observations to be made:

- The activity concentration of alpha-emitting nuclides (Am-241, Pu isotopes, Cm-244) is on the order of 10 Bq/g in both tanks. Hence the initial assessment of the waste as class LLW is confirmed via the pre-existing data and further analysis of this classification is not necessary.
- The activity concentrations in the two tanks are not significantly different with ratios for individual nuclides ranging between some tenths to some tens.
- The nuclide activity concentration in tank VA001 is not representative of a homogeneous distribution, with standard deviations of the activities up to 200 %. In tank VA002, the homogeneity is significantly higher, with standard deviations not exceeding some 20 % for the activities.
- No information is available about the about the elevation level within the tank from which sampling occurs.
- The activity concentration in the samples is dominated by fission products. The ratio of Sr-90 to Cs-137 activities is very high (around 0.5 to 0.6 in both tanks, while usually a ratio between 0.1 and 0.01 is more typical). In reference International Atomic Energy Agency (2009), typical scaling factors for Italian nuclear power plants are listed, however they refer only to the four commercial nuclear reactors, two of the BWR type and one of the PWR type and gas graphite type each. The example mentioned here, the ratio of Sr-90/Cs-137 activities, is less than 0.06 in resins from BWR and PWR reactors listed in that IAEA reference.
- In both tanks there is very little solid material present, but nevertheless the $\alpha/\beta\gamma$ ratio is high compared to standard reactors (PWR, BWR). Tank VA002 probably contains more solid (95% water) compared to VA001 (99%). Nevertheless the $\alpha/\beta\gamma$ ratio in VA001 seems to be larger than in VA002. Alpha emitting nuclides are expected to be more present in the solid due to their low solubility. In summary, both tanks have a relatively high $\alpha/\beta\gamma$ ratio when compared with standard reactors. The higher $\alpha/\beta\gamma$ ratio combined with higher Sr-90/Cs-137 can also be found in spent fuel residues.
- For a statistically valid application of scaling factors, more data of DTM nuclide activities will be needed for both tanks. For tank VA001, the applicability of scaling factors is severely limited by the variability in activity concentrations, while for tank VA002, scaling factors based on the Co-60 and Cs-137 activities were of limited applicability.
- In the existing data, many of the activities of DTM nuclides were below the detection limit. However, valid characterisation of the nuclide vectors will require more information about the homogeneity, and of the usefulness of applicable scaling factors. More data will therefore be needed, including of DTM nuclides.

5.5 Achievement of the objectives

The pre-existing data provide comprehensive information about physico-chemical properties of the waste. Only a small number of additional samples (e.g. 6 per tank) should suffice to confirm the characteristics determined via the pre-existing data.

In the context of historical information, it is known that the sampling was conducted immediately following tank filling and mixing; hence information about an elevation profile in activity concentrations or sludge/liquid separation is not available from that data set, and additional sampling will need to verify if such a profile exists in the tanks.

Based on the pre-existing data, the radionuclide inventory of the tanks is less homogeneous than the chemical content, which also suggests additional data will be needed to obtain a statistically valid radionuclide inventory and, if possible, relevant scaling factors.

The objectives relating to variability and nuclide content of the radioactivity in the two tanks are therefore not adequately addressed by the pre-existing data, and more sampling (both non-destructive and destructive) will have to be performed.

6 Sampling plan – design

6.1 Non-destructive testing to determine possible elevation profile in activity

The first step in the sampling campaign should be the establishment of the approximate distribution of the activity in the tanks by external gamma spectrometry or by collimated dose rate measurements. The prerogative here would be to determine if there is an elevation profile in activity concentration within the tanks, for example as a result of solids with more significant radionuclide content settling to the bottom of the tanks, hence this campaign should be performed prior to mixing, and after allowing as long a settling time as possible. This is likely to give an indication of the separation within the tanks between liquid and sludge portions of the waste, and therefore also allow an estimate of the respective quantities of sludge and liquid present.

The pre-existing data of tank VA001 displayed relative inhomogeneity – this inhomogeneity may be related to sampling different portions of the sludge without adequate mixing. Non-destructive testing from the tank exterior may be useful to determine if this is the case in the present situation, i.e. if there is an elevation profile with differing activity concentrations. This is particularly relevant as at present, several years after the first samples were collected, stratification or deposition may have occurred.

For tank VA002, the sampling data suggested better homogeneity between the samples. Nevertheless, the same technique should be used to determine whether an elevation profile can be determined exterior to the tank prior to mixing.

6.2 Biased sampling, prior to mixing

Following non-destructive gamma dose rate measurements, there will be an indication of whether the contents are fairly homogeneous with respect to specific activity, or whether there is a significant elevation profile.

In case of an elevation profile, biased sampling should be performed on that portion of the waste with the highest activity contained, prior to performing any mixing. The number of samples to take may be limited by access of the different levels within the tank, but a minimum number of samples of about 6 may be sufficient for confirming the usefulness and applicability of previously identified scaling factors.

6.3 Unbiased sampling, following mixing

In case of no elevation profile, sampling can skip the previous step (biased sampling) and can proceed to unbiased sampling, which should be performed after mixing tank contents. If possible, unbiased sampling should be performed in a way as to ensure that any part of the tank contents is equally likely to be sampled.

Therefore, only the probabilistic sampling method can now be used for sampling the sludge. To ensure a valid random sampling campaign for the entire volume, it has to be ensured

- that the entire mobilisable volume of the tank is circulated during the sampling campaign and
- samples are taken from (nearly) equal volumes from the whole stream.

The minimum number of samples is determined by the requirements of an approach for univariate statistics on non-spatially distributed data. As preparatory homogenisation measures will be used for homogenisation, the expected variance of activity concentration should be low. Therefore, the number of samples can be low (10 to 20).

If step 6.2 was skipped, the number of samples of this step will need to be sufficient for determination of scaling factors and range of nuclide factors. If data were collected for step 6.2 (biased sampling), the number of samples still required for the unbiased sampling step can be correspondingly reduced, as the biased sampling data can provide some information about the results to be expected after mixing.

Statistic evaluation of results will be done concerning univariate analysis only with respect to the nuclide specific activity concentration. In addition, the scaling factors of DTM to Cs-137 will be evaluated or confirmed.

Based on the pre-existing data, it can be expected (but needs confirmation) that no activity elevation profile can be found for tank VA002, while for tank VA001, an elevation profile is likely but also needs confirmation. If an elevation profile exists, biased sampling will confirm this, and the sampling data can be contributed to the data set used for characterization. If no elevation profile is identified, non-biased sampling only will need to provide sufficient data for characterization.

6.4 Number of samples

How many samples are required?

According to Pérot et al (2017), the simplest approach for a univariate problem with no spatial structure is to use the standard formula

$$n \geq (\frac{z\sigma}{e})^2,$$

Where n is the number of samples, z is the confidence level, σ is the sample standard deviation and e the error level. It is clear that the number of samples increases rapidly with the standard deviation, i.e. with the variability of the sample set. For the data set for tank VA001, values for the standard deviation in activity concentration ranged between 16 and almost 200 % of the mean. Assuming a confidence level of 90 % (i.e. $z = 1.6$) and an error of 5 % of the mean, the number of samples required from this set is still at least 20, when assuming the lowest value for the standard deviation found (16 % for Co-60). For the sample set from tank VA002, the situation is slightly more advantageous, as the variability in the data was smaller. For this set, the number of samples required is at least 5, and up to about 60 for the nuclides for which the activity concentration displayed larger variability.

In a first step therefore, it is advisable to confirm the amount of variability in the data before deciding on the number of samples required. In the case of a spatial structure being present (as determined in step 6.1), biased sampling of individual layers will lead to more homogeneous subsets for sampling, which require a smaller number of samples. As a starting point, 6 samples should be sufficient to confirm variability and inform the way forward.

7 Conclusion

Following the guideline set out in D3.2 Report on statistical approach, see Rogiers *et al* 2018, we attempt here to follow the proposed strategy by applying it to the characterisation of the Ispra storage tanks.

The amount of effort needed for the sampling and characterization campaign hinges on the availability of information prior to the campaign. Information about the historical origin of the waste and the analysis of pre-existing data can significantly reduce the subsequent sampling required.

The two LLW tanks at Ispra are characterized by activity concentrations of gamma emitting nuclides of a few Bq/g (tank VA001) up to about 135 Bq/g (tank VA002). Non-destructive gamma spectrometry from the tank surface may be used to determine if elevation profiles in the tank can be identified prior to mixing.

Biased sampling may be used to confirm inhomogeneity within the tanks, if suggested by non-destructive testing. If not, non-biased sampling only can be used to confirm the trends observed in the pre-existing data, and to supplement it where additional information is needed.

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Appendix: Pre-characterisation sampling questionnaire: liquid effluent storage tanks at JRC, Ispra

In the context of the INSIDER project, the liquid waste storage facility (the so-called “tank farm”) of the Joint Research Centre (JRC) at Ispra has been selected as a “use case” scenario for the application of the statistical sampling strategy developed in the project. The sampling plan to be developed for the use case is intended to serve as a blueprint for validating techniques through inter-laboratory comparison and benchmarking.

In order to establish the data quality objectives for the sampling strategy, the boundary conditions of the decommissioning scenario have to be established. In particular, clear objectives for radiological characterisation need to be defined, end points defined and as much information provided as is available. These objectives may be addressed in the form of a questionnaire aimed at optimising the utilisation of available information:

1. Q: Identify the requirements and targets for the radiological characterisation campaign:

№	Question	Answer
1	State the problem: why is characterisation needed, and in what context? What existing information is available?	Characterization of waste is the first stage of removal from operation and is performed in the following order: • Planning to ensure biological protection during RW management operations; • Selection of the necessary equipment for transportation, treatment, handling and storage of radioactive waste; • Selection of suitable technological methods for the processing of RW.
2	Identify the goals of the study: what is the expected outcome or use for the data?	The following parameters are required for characterization of the waste: • RW activity (high-activity, medium-active and low-activity). • Types of activity (α, β, γ-activity, transuranic elements are singled out separately, as well as groups of individual radionuclides H-3, C-14, Cl-36, Ca-45, Mn-53, Fe-55, Ni-59, Ni-63, Nb-93m, Tc-99, Cd-109, Cs-135, Pm-147, Sm-151, Tm-171, Tl-204). • Radioactive half-life (short-existing and long-existing) of elements. • Physical form of RW (liquid/solid, combustible/non-combustible). Classification according to these characteristics determines the suitable activities for handling, processing and storage of the radioactive waste.

3	Identify the information inputs: what do we know, and what do we need to know?	The initial data is: • History of RW origin • Results of previous measurements of activity and dose rate from containers • Data about previous studies of the waste. • Data on the design of the container. • Data on the aggregate state and physical properties of RW. Data about the time after the localization of radioactive waste in the storage system.
4	Define the boundaries of the study, i.e. which limitations and conditions apply?	As a result of the study, it is necessary to obtain a set of data necessary for the planning and organization of radioactive waste management, including the stages of extraction, processing and disposal. Additional requirements can also be identified and specified by national regulatory bodies, including future use of waste and technology to be used for disposal.

2. Q: What is the historical origin of the waste?

№	Question	Answer
1	Include historical records on installation licensing and operations.	The waste proposed for the study was formed as a result of the operation of a nuclear research facility, which determines the presence of a full spectrum of α,β,γ-emitting nuclides.
2	Are periodic reports on environmental surveillance, radiological monitoring etc. available?	Currently, there are reports of chemical and radiological study of the sample set: • E1265 - Final Analysis Report - WoPa 03-2011 - WoBa 1 - ver.02; • E1265 - Final Analysis Report - WoPa 04-2012. These reports provide information on the samples taken and the results of the analysis, in particular: • Physical property. • Chemical composition. • Isotopic composition. Reports are provided.

3	Where available and where relevant, provide information on operational incidents and procedures.	No accidents occurred in the facility since its entry in operation.
4	Highlight areas where there are gaps or inconsistencies in available information or where there are significant uncertainties regarding potential risks or hazards.	In our view, the main uncertainty is the uneven distribution of radioactive substances in the storage system. In particular, during the storage of liquid radioactive waste, a precipitate with an increased activity relative to the liquid fraction is formed. Determining the isotopic composition and amount of sedimentary fraction is the most uncertain and difficult task.

3. Q: What is the chemical origin of the waste?

№	Question	Answer
1	What is the composition and physical form of the waste?	The object of the study is liquid radioactive waste. The results of the study of prototypes are presented in the reports: • E1265 - Final Analysis Report - WoPa 03-2011 - WoBa 1 - ver.02; • E1265 - Final Analysis Report - WoPa 04-2012.
2	Give information about toxicity of materials.	No evidence of presence of toxic elements.
3	Provide classification in terms of hazardous substances.	From preliminary analyses the two tanks in the INSIDER exercise are expected to contain liquid waste of category low level (LLW); in the facility there is a smaller tank containing intermediate level liquid waste (ILW), but this is not included in the exercise.

4. Q: What is the radiological origin of the waste (origin of and potential for contamination and activation)?

№	Question	Answer
1	What is the source of waste?	Radioactive waste formed in the process of operation of nuclear research installations. A brief description of the installation is provided in the document above.

		Material data safety sheets about the waste do not exist.
2	Provide existing radiological characterisation (obtained e.g. during operations, and during transition phase).	From the laboratory studies of the samples it follows that the data contain long-lived α,β,γ-emitting nuclides, including transuranic elements.
3	Provide information on radionuclides identified or detected in operational surveys, from effluents and wastes.	The most significant are isotopes of caesium, strontium, cobalt and plutonium.

5. Q: What are the variables of interest? (Radiological inventory, dose rates, waste classification, isotopic composition, etc)?

№	**Question**	**Answer**
1	Identify the radionuclides of interest for characterisation, referring where relevant to the isotopic composition of the waste.	The most important characteristics are: • specific activity of each fraction (LRW and sludge); • isotopic composition; • dose rate at waste container.
2	Is there information on the estimated correlation factors between hard-to-measure radionuclides and key nuclides?	Two sets of scaling factors are available from the plant characterization reports of the plants from which the liquids stored in the tanks originated.
3	Is there information about appropriate measurement techniques, and have techniques been tested?	Currently, information is available on laboratory studies of the samples taken. There is no detailed description of methods of research and verification of these methods.
4	Provide information about dose rates at the site.	Maximum dose rate at contact of tanks is 30 µSv/h.

6. Q: What is the accessibility of the waste?

№	**Question**	**Answer**
1	Describe physical access to the site and to the waste	Access to the JRC Ispra site is controlled, but permits can be obtained easily with one-day

	containers, listing relevant access limitations and constraints.	notice for EU nationals. Access to the facility requires an extra permit; moreover it implies health physics formalities that require planning with some preparation time (at least two weeks).
2	Describe constraints as a result of spatial arrangement, physical constraints such as high dose rates, presence of hazardous conditions.	The tanks are in a large building easily accessible from one side. Part of one tank (nearly half of the front side) is protected by a shield, thereby reducing accessibility. There is limited space to move around and below the tanks. It is possible to access the top.

7. Q: What information is available about the homogeneity of the waste?
   A: The data presented in the reports on the study of prototypes show that there are significant differences between different fractions of RW (liquid fraction and sedimentary fraction) in specific activity.
   The tanks are equipped with stirrers that should help to homogenize the liquid part. Nevertheless some preliminary tests performed with gamma cameras show that there is substantially larger activity at the bottom of the tanks and that the situation does not change significantly during and after mixing. This could indicate that there is some solid deposition on the bottom of the tanks.

8. Q: Are there additional requirements relating to in-field sampling (e.g. containment, transport, storage requirements)?
   A: Previous experiences during characterization campaigns show that samples from the tanks up to half-liter can be easily shipped to laboratories as exempt packages.

9. Q: What is the intended end stage for the waste? Are plans in place for disposal or long term storage?

№	Question	Answer
1	What plans exist for conditioning of the waste?	There are plans for recycling, landfill and site remediation. Brief information is provided in Brochure Nuclear Decommissioning and waste management Programme at the joint Research Centre, Ispra site (provided).
2	What plans exist for dismantling activities?	
3	What planning is in place for remediation and waste disposal?	
4	What options are available for residual materials?	

10. Q: Give references to similar installations if available.

11. Q: Are there any specific requirements for analysis, reporting and stakeholder engagement post sampling?
    A: Similar samplings have been done in the past under the existing license. No special formalities or authorizations from regulatory bodies are required.