Characterization of Legacy Low Level Waste at the SVAFO Facility using Gamma Non-Destructive Assay and X-Ray Non-Destructive Examination Techniques - 11405

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ABSTRACT

At the SVAFO facility, which is located on the Studsvik site near Nyköping, Sweden, approximately 7000 drums containing legacy low level radioactive waste are stored at four locations. The majority of the waste drums (>6000) were produced between 1969 and 1979. Production of the remainder continued from 1980 onwards.

Characterization of the waste is performed using a combination of techniques via mobile equipment located in the AU building at the SVAFO site. Each drum is weighed and a dose rate measurement is recorded. Gamma spectroscopy is used to measure and to estimate radionuclide content, and real time x-ray examination is performed to identify such prohibited items as free liquids.

INRODUCTION

AB SVAFO is responsible for the remediation, decommissioning and management of Sweden's historic radioactive waste and nuclear facilities. SVAFO's legacy waste is in need of further characterization before it can be brought to the final repository for long lived, low and intermediate radioactive waste (SFL). This facility will be built by SKB, the Swedish Nuclear Fuel and Waste Management Company, which is tasked with managing and disposing safely of Swedish nuclear and radioactive waste. It will be operational around the middle of the 21st century.

The characterization activities will improve the knowledge of the drum content and are expected to satisfy some of the discrepancies or omissions that exist between the present government regulations and current waste documentation. All parameters that are possible to measure will be reported. However, while it is expected that some information, such as the TRU content, may never be possible to determine fully and accurately, other data and information gained from this project could be used by SKB during development of the waste acceptance criteria for the future SFL repository.

It is critical that the presence or absence of free liquids is determined. Liquids are not allowed in current repositories and it is expected that this will be the same for Sweden's SFL repository. Liquids found in the waste may be removed during possible future waste conditioning. Alternatively, if the liquid content cannot or should not be removed to be compliant with the ALARA principle, the estimated liquid volume may be used as design parameters for the future SFL repository.

In addition to improved knowledge regarding liquids, real time x-ray examination will also provide a better understanding of the overall waste matrix by identifying the presence of shielded containers, possible fissile materials and other objects of interest such as possible pressurized containers. Furthermore, high resolution gamma spectroscopy (HRGS), the gross waste drum weight and a gamma dose rate measurement will enhance the knowledge of the radionuclide inventory since this has to be accounted for according to government and repository safety assessment regulations.

DESCRIPTION OF DRUMS

The radioactive waste resides in a waste container in the form of a wire mesh basket or a 100 litre metal drum. Each waste container was then placed in a 200 litre drum. The space between the 200 litre drum and the waste container was filled with concrete. A cap of concrete was added so that the waste is completely enclosed by a layer of concrete. The vast majority of the 200 litre drums have already been placed in 280 litre ‘overpack’ drums of height 960 mm and diameter 650 mm. The remaining 200 litre waste drums are placed in 280 litre overpack drums immediately prior to characterization. The gross weight of the 280 litre waste drums ranges from 200kg to 700kg.

The geometry is based on assumptions for the waste drums as shown in Table 1 and a cross-section of the generic waste drum geometry is shown in Figure 1.

	Outer Diameter (mm)	Height (mm)	Wall Thickness (mm)	Top Thickness (mm)	Bottom Thickness (mm)	Material Type	Density (kg/m^3)
Outer Steel Cylinder	650	960	1	1,5	1,5	Steel (DIN-EN 101330)	7800
Inner Steel Cylinder	575	880	1	1	1	Steel (DIN-EN 101330)	7800
Concrete Cylinder	573	808	70	50	50	Concrete	2300
Waste Matrix	433	708	-	-	-	-	490

Table 1: Generic Geometry of Waste Drums

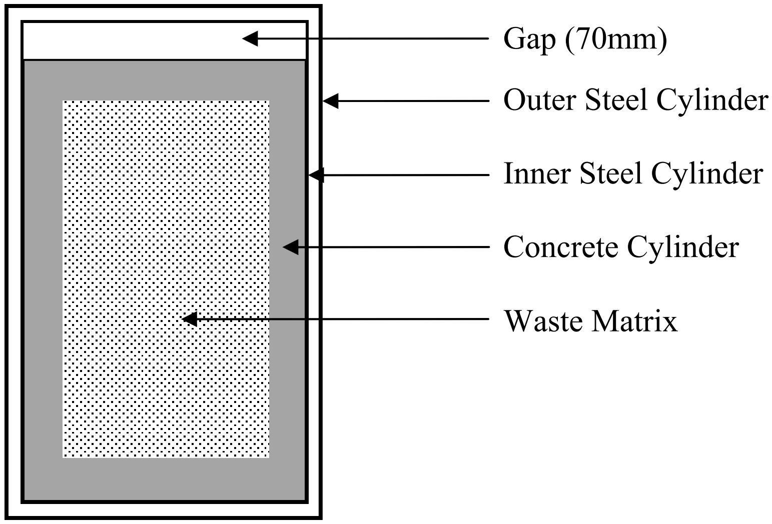

Figure 1: Cross-Section of Generic Drum Geometry

DRUM CHARACTERIZATION

Characterization of the waste drums is performed using a combination of techniques via mobile equipment located in the AU building at the SVAFO site.

Figure 2 shows the location of the waste drums, the drum staging area and the drum characterization area within the AU building where the majority of drums are currently stored.

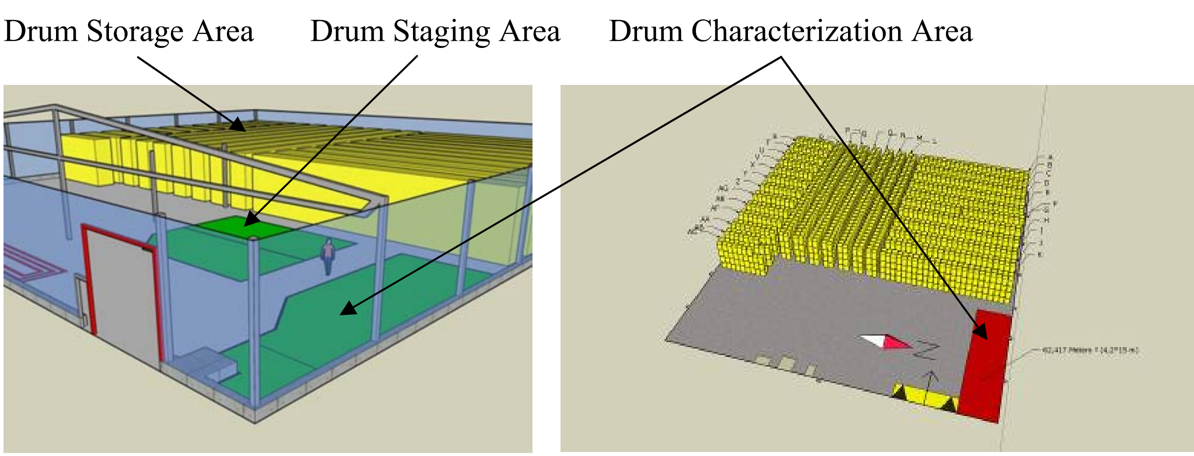

Figure 2: Layout within AU Building

A batch of drums is selected from the storage area and moved to the drum staging area. From there, each drum is moved into the drum characterization area for characterization and afterwards back to the drum staging area. The drum staging area is divided into two sections; one for drums awaiting characterization and one for drums which have been characterized.

In the drum characterization area each drum is weighed on a rotating, weighing turntable. The drum is rotated during which the gamma dose rate is measured at its mid-height at 1m from the surface and HRGS is performed using an In-Situ Object Counting System (ISOCS). This comprises a shielded/collimated Broad Energy Germanium Detector, spectroscopy data acquisition system and gamma assay software including interactive peak fit routines. The distance of the HRGS detector from the drum can be varied from 1 to 4 metres to maintain an appropriate detector dead time for all waste drums.

The generic geometry in Table 1 is used to determine the efficiency of the HRGS detector needed for the calculation of the activities of the directly measured gamma radionuclides. The density of the waste matrix and the radionuclide content within it are assumed to be homogeneously distributed. The activities of "hard-to-measure" radionuclides, using inference from an appropriate waste stream fingerprint, are not determined.

Each waste drum is then introduced into a shielded x-ray vault for real time radioscopic (RTR) examination using x-ray energies of up to 450kV. Figure 3 shows the shielded vault with a waste drum on the drum manipulator enabling three degrees of movement (i.e. vertical, translational and rotational). The x-ray tube housing, x-ray shutter and the imaging detector housing are also shown. The x-ray tube housing minimizes leakage radiation from the tube. The x-ray shutter allows the primary beam from the x-ray source to be collimated as required by the operator during inspection of the waste drum.

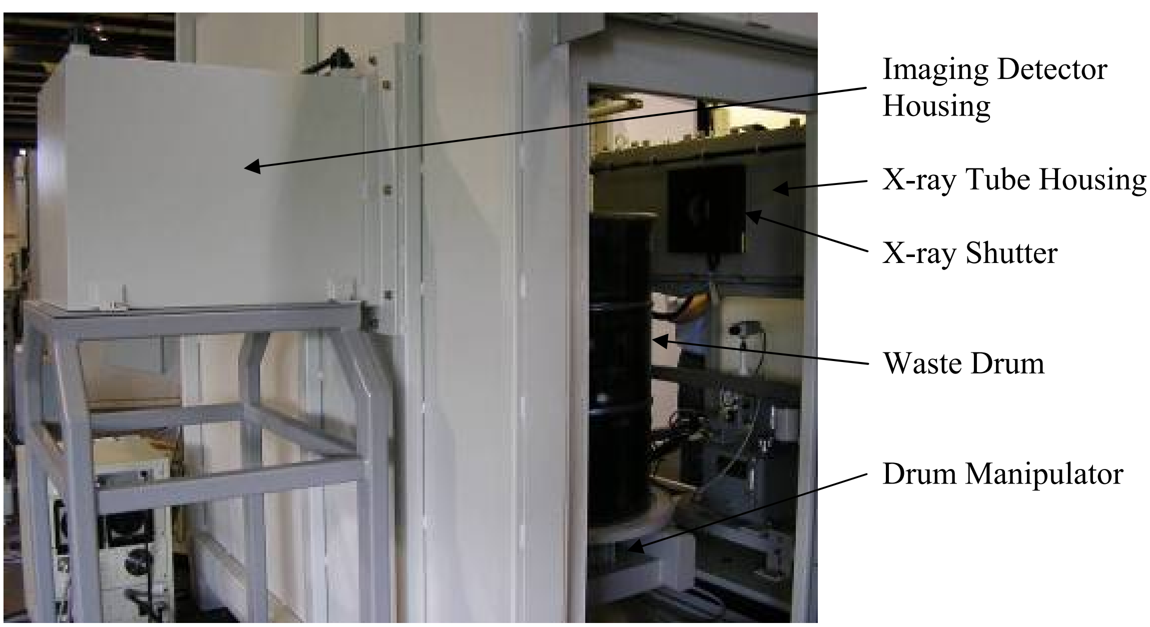

Figure 3: X-Ray Vault and Equipment

RTR examination enables the operator to identify the following:

- Objects containing free liquids, and an estimate of the total volume of liquid.
- Glass containers, or similar, that could hold liquids.
- Denser objects (possible fissile material or mercury).
- Containers found in the waste matrix that are too dense to image (possible radiation shielded containers).
- Any other items of interest such as possible pressurized containers (e.g. aerosol cans).
- Drums with a density too high to be penetrated and effectively imaged using energies of 450kV.

System performance quality checks are performed before the start of characterization work each day. A radioactive test source is used to confirm energy calibration, energy resolution and correct operation of the germanium detector's electronic counting chain. A background spectrum is collected to check for statistically significant changes in the background radiation level. A standard image quality gauge is used to check the spatial resolution of the RTR imaging system.

Using the ISOCS and rotating weighing turntable, the following data are recorded for each characterized waste drum:

- Date, time, unique drum identification number, gross weight, gamma dose rate at mid-height at 1m.
- Acquired gamma spectrum.
- Gamma spectrum analysis report.
- A text file reporting the calculated activities with measurement uncertainties, or Minimum Detectable Activities (MDAs), of several key radionuclides plus any others identified above their MDAs in the SVAFO nuclide library.

The operator records the RTR examination of each characterized drum on to two DVDs together with relevant audible commentary. In addition, the following information for each drum is recorded in a spreadsheet:

- Date, time, unique drum identification number, operator name and DVD number.
- Total estimated liquid volume.
- Approximate percentage of drum volume that can be adequately imaged.
- Number of radiation shielded containers.
- Suspicion of fissile material.
- Any other observations and any problems encountered.

CHARACTERIZATION RESULTS

The characterization of 5177 drums has been completed representing 70% of SVAFO's legacy low level waste within the scope of this project. The average production rate is approximately 20 drums per working day using two qualified operators. The remaining waste drums will be characterized during the first half of 2011.

The background radiation from the approximately 5000 waste drums located within the AU building is minimized by the use of the ISOCS' standard set of 50mm thick lead shields fitted around the germanium detector. This is supplemented to the sides and rear by a concrete block wall 600mm thick. Finally, the remaining photopeak counts in the background spectrum are subtracted from the appropriate net peak area of detected radionuclides from the waste drum using a System Background spectrum.

All waste drums are characterized using a fixed live time of 15 minutes. MDAs for some key radionuclides, when no other radionuclides are detected above their MDAs, are shown in Table 2.

Radionuclide	MDA (Bq)
Co-60	≈ 2.2 E4
Cs-137	≈ 4.3 E4
U-235	≈ 2.3 E5
U-238	≈ 2.9 E6
Am-241	≈ 1.1 E8

Table 2: MDAs for some Key Radionuclides

The statistical measurement uncertainty is small in comparison to the geometrical uncertainty due to possible deviations from the assumed generic waste drum geometry in Table 1. The effect of the geometrical uncertainty on the total measurement uncertainty and on the MDAs is greater for the lower energy radionuclides. Also, the lower the energy of the detected radionuclide, the greater the effect on its MDA and total measurement uncertainty due to the presence of Compton scattered radiation in the background from higher energy radionuclides.

The waste acceptance criteria for the SFL repository will include upper limits for some key radionuclides. It is worth noting therefore that the sum of the measurement uncertainties is much smaller than the sum of the upper uncertainty values. Consequently, an unacceptable proportion of the capacity of the SFL repository is unlikely to be used unnecessarily by 'phantom' activity arising from these measurement uncertainties.

The measurement accuracy has been determined largely by practical considerations, primarily throughput to enable characterization of over 7000 drums in less than two years. If, prior to final storage, the measurement accuracy is deemed unacceptable, it could be improved by further analysis of the collected data without the need to remeasure the waste drums. For example, the gross drum weight and determination of the concrete thickness surrounding the waste matrix from the RTR images could be used to improve the ISOCS's geometrical model for waste matrix shielding and mean waste density.

The measurement time for RTR examination ranges from less than 6 minutes to in excess of 15 minutes with a typical drum taking about 10 minutes. It is dependent upon the complexity of the waste matrix under examination and the gross weight of the drum. The shortest examinations are for the lightest drums with little, simple or low density matrices. Very heavy drums (i.e. >500kg) are also quick to examine as these are too dense to image effectively with 450kV generated x-rays. Heavy waste drums (i.e. >400kg) or those with complicated matrices take the longest to examine. Examples include:

- Many small containers packed tightly together such that detecting small volumes of free liquids is difficult.
- Stratified matrices comprising alternating layers of dense and low density regions resulting in an image contrast which it too great to image simultaneously.
- Low density waste mixed with concrete giving the same image contrast difficulty.
- Dense matrices producing dark RTR images in which waste items are difficult to identify even with the x-ray tube at maximum voltage and a high current setting.

Whilst the gross weight of the waste drums ranges from 200kg to 700kg, most drums weigh 300kg to 400kg. Some key measurement results from the RTR examinations are shown in Table 3.

Parameter	Number of Drums	Percentage of Drums
Containing free liquids	1456	28.1
Total estimated liquid volume	≈ 2957 litres	
Suspicion of fissile material	567	11.0
Containing radiation shielded containers	514	9.9
Containing mercury	35	0.7
Possible pressurized containers	26	0.5
Not possible to image adequately at least 80% of volume of waste matrix	1549	29.9

Table 3: Key Measurement Results from RTR Examinations

The minimum liquid volume which can be detected reliably is 5ml to 10ml.

The maximum drum weight for which greater than 80% of the volume of a homogeneous waste matrix can be imaged adequately is approximately 420kg.

CONCLUSION/IMPORTANCE OF THIS WORK

SVAFO's legacy waste is in need of further characterization before it can be brought to Sweden’s SFL repository in order to resolve some of the discrepancies between the present government regulations and the existing waste documentation. It is recognized that information gained by this exercise, and reported, could be used by SKB during development of the waste acceptance criteria for the future SFL repository.

Information regarding the presence of items currently prohibited from being introduced into final repositories, such as free liquids and radiation shielded containers, will enable informed ALARA based choices to be made regarding waste disposal. For example, the prohibited items could be removed from the waste or, alternatively, the waste characterization data could be used in the design of a SFL repository able to accept the un-remediated waste.