Characterization and Clearance of m/s Sigyn

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ASTRACT

*M/s Sigyn (**Fel! Hittar inte referenskälla.**) was a 2044 ton ship that transported contaminated material between 1982 and 2013. Most of the transports were with spent nuclear fuel between Swedish nuclear power plants and the Swedish fuel repository, Clab. In addition to spent fuel, m/s Sigyn also transported big contaminated components, from nuclear power plants in Europe, to Studsvik for analysis or decontamination and melting. She also transported components from Swedish nuclear power plants to final disposal of short lived waste, SFR. Even though all transported items have been cleaned, checked and wrapped with plastics, some activity ended up as contamination onboard. In December 2013 it was decided that m/s Sigyn was subject for decommissioning due to her age. This Paper describes the method in which the activity onboard m/s Sigyn was characterized and clearance levels were calculated.*

Figure 1: m/s Sigyn

This method for radiological characterization and clearance has recently been developed in Sweden, the method is efficient in that it does not need a big pre characterization survey. Only the nuclide distribution and history of the object, is needed to start the final survey. In the future there will be further development of the method, making it possible to reduce the number of measurements even more. This will further optimize the method and reduce the cost for final surveys and clearance.

INTRODUCTION

There are several methods to analyze activity for a contaminated object, building or land area, used around the world. Some are more effective than others but all of them have advantages and disadvantages. This paper describes the method in which m/s Sigyn was characterized and clearance levels were calculated.

This was the first time clearance for free release was attempted in Sweden, on an object of this size.

DESCRIPTION

The method used to characterize m/s Sigyn and calculate her clearance levels can be divided into seven steps described below:

Analysis of nuclide distribution in contamination

By analyzing the transports made by m/s Sigyn, a general nuclide fingerprint was set for the activity onboard. The transports of used fuel were, according to the logbooks three times as much from BWR than from PWR, the same was true for contaminated material. The assumed average fuel burnout was 34 MWd/kgU for BWR fuel and 41 MWd/kgU for PWR fuel. According to the logbooks most of the transports that resulted in contamination were performed in m/s Sigyn's early years. Contaminated internals and used fuel are normally stored on site for a few years, to account for this an assumed decay time of 20 years was used to calculate the nuclide distribution.

Detector effectiveness

Measurements of the contamination were made with scintillation detectors. By measuring both beta + gamma and background gamma radiation at the same location and by multiplying the net value with a beta-effectiveness for the detector, a result in Bq/m^2 for the contamination could be calculated. The key component in this is the scintillation detector effectiveness, the effectiveness is calculated using known facts about the nuclide distribution, beta energies per nuclide and hardware (in this case scintillation detectors) data.

Exclusion of hotspots

Hotspots are a general problem in clearance for decommissioning and they have historically been found on m/s Sigyn. A scintillation hotspot scan value was calculated using the nuclide distribution, results from scintillation and nuclide specific measurements on a previously found hotspot. For m/s Sigyn the scan value was 1000 counts per second (cps) on the surface for a hotspot with an activity at the free release limit. When scanning the ship for hotspots no further hotspots were found exceeding the scintillation hotspot scan value.

Categorization of surfaces

By eliminating the risk for hotspots, the surfaces and components onboard were able to be categorized by the risk for contamination. The risk category

determines the number of measurements needed. The risk categories and the amount of area coverage needed are shown in Table 1.

TABLE 1. Risk categories for surfaces

Category nr.	Risk categories for surfaces	Number of measurements
1	Contaminated over clearance limits	1 % of surface
2	Risk for contamination over clearance limits	1 % of surface
3	Low risk for contamination over clearance limits	0.1 % of surface
4	Extremly low risk for contamination over clearance limits	0 % of surface

There were no surfaces categorized as category 1. The amount of surfaces and areas per category and the amount of measurements points are shown in Table 2.

TABLE 2. Number of areas, total area and amount of Measurements points per category

Category	Number of areas	Area [m^2]	Measurement points
1	0	0	0
2	19	1483	202
3	8	980	995
4	1	not calculated	0

The categorization was based on how the ship was used and on where the previous contamination had been found. The preliminary risk categorization started by categorizing the transportation space as category 2. The surfaces contaminated by staff having stepped in contamination and then spread it to rooms nearby the transportation space are categorized as category 3. I.e. the risk categories fall with one category number per room away from the transport space. Walls have a risk category lower than the floor in the same room. Contamination spread through the air from components in the transport space has passed the outgoing ventilation system. The surfaces of the outgoing ventilation system were therefore categorized as category 2. The ceiling of the transport space has a risk category lower than the nearby outgoing ventilation, category 3. Areas where contamination should have been accumulated e.g. water wells, sludge pump, filters and collection trays collecting waste water from the transport space is categorized as category 2.

Note that the statistics do not demand measurements of a percentage of the surface. Measuring a percentage of the surface area is more of a tradition in Swedish clearance work. Future projects will probably reduce the amount of measurements further. This was not done in this project because of the already small amount of measurements.

There is no need to measure a greater proportion of the surface area for a category 1 area, than a category 2 area. 1 % is enough for the required decisions and uncertainty levels.

Measurements of homogeneous units

The surfaces categorized as 1, 2 or 3 were divided into units with an equal Gaussian distribution of contamination. By dividing areas into units with assumed equal Gaussian distribution, the resulting measurements are possible to analyze with Bayesian statistics. Dividing the contaminated areas was done in three steps;

- First step was to use knowledge based on statistical physics and years of contamination experience to divide the areas into smaller units with similar assumed Gaussian distributions.
- The second step was to do the measurements at randomly distributed locations, with the number of measurements based on the risk categories described in Table 1. The measurement techniques used are shown in Figure 2.
- The third step was to analyze the data and verify that the correct area boundaries were used in the first step. If data showed non normal or log normal distributions, i.e. that the areas were wrongly divided into homogeneous units, the areas were divided into new units. New measurements were added if the previous number of measurements in the units were too small. An example of a normal probability plot for a measurement unit is shown in Figure 3.

In addition to the randomly distributed measurement locations discussed above, a small number of extra measurements were done. The locations of these extra measurements were chosen by the measurement team. The locations were where the risk for contamination was as high as possible for every unit according to the measurement teams great experience of locating contamination, it may be spaces like corners, joints and pockets.

Figure 2: Measurement techniques

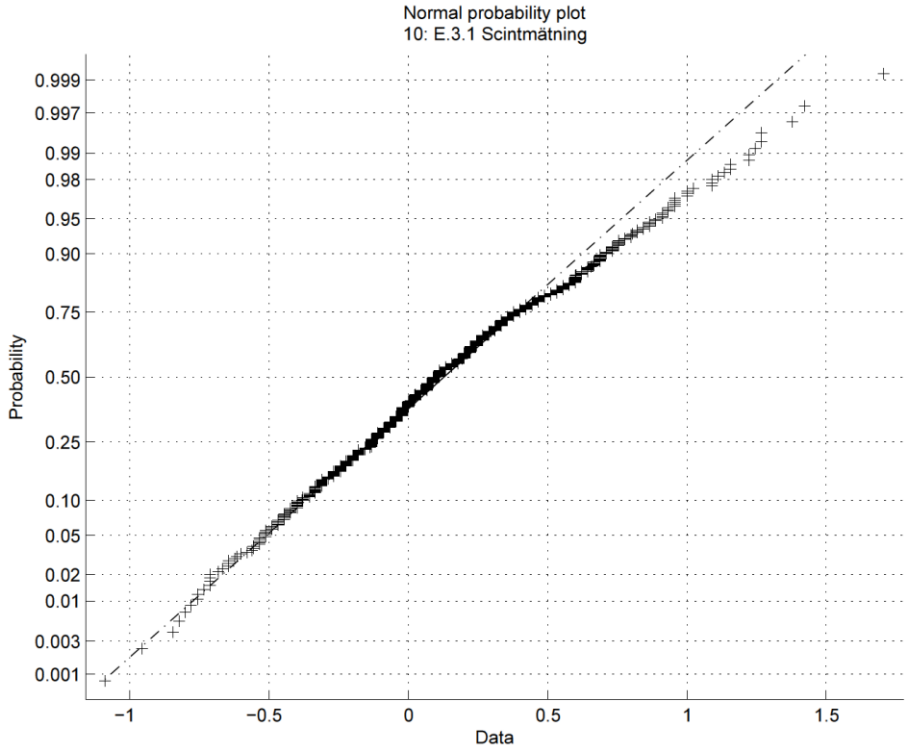

Figure 3: Plot of data from the biggest area classified as risk.

Bayesian statistics

By using randomized positions for the measurements we were able to verify the Gaussian distribution and calculate an upper 95 % credibility level for the contamination by using Bayesian statistics. The statistics is further described in a paper presented at the Workshop on radiological characterization for decommissioning, Studsvik 2012 [1].

Comparison with clearance levels

The calculated activity with a credibility of 95 % for every proven homogeneous unit was then compared to the clearance levels given in SSMFS 2011:2 [2]. Of the 27 units, no one was contaminated above the clearance limits. The area closest to the clearance limits was contaminated below 48 % of the limits with 95 % credibility. On average the areas were contaminated below 15 % of limits with 95 % credibility when m/s Sigyn was analyzed as a material.

DISCUSSION AND CONCLUSION

The advantage of using Bayesian statistics is that the contamination is proven to be homogenous for every unit and presented as below a level with 95 % credibility, there is therefore no need for limitations on the size of the units.

By proving that the units are homogenously contaminated and analyzing the result with Bayesian statistics, the amount of measurements can be reduced to far less than 100 % of the surface. If the risk category is lower the expected contamination level is lower, the lower the contamination levels that are compared to the clearance levels, the fewer measurements are needed to prove that the UCL are below clearance levels. The measurement percent of area per risk category used in this m/s Sigyn project was taken from the early stages of the big decommissioning project of Ranstad. Ranstad decommissioning project is an ongoing project in Sweden with the purpose to deconstruct a Uranium mine [1].

The method used in this study has little need for pre surveys, in a case like this. The nuclide distribution and history of the object was all information needed to start the final survey. Instruments used for measurements were alfa/beta/gamma scintillations detectors which are cheap, easy to use and flexible. In this project there was only need for material samples to verify the nuclide distribution. This method is therefore a relatively fast and cheap way to characterize an object like m/s Sigyn.

This method was selected because it is fast, cheap and do not need a major pre survey. It also had the advantage of already having been approved by the Swedish authority during the Ranstad decommissioning project [1]. By using other methods for example those described in MARSSIM [3], would further decrease the amount of measurements for this project because the contamination levels onboard were low. But if the contamination levels would have been closer to the clearance levels the method used in this project require less decontamination and pre surveys compared to the MARSSIM method.

Arguing with the Swedish regulatory for approval of another method or a combined method would have cost time and the possible gain was not in proportion to this estimated time loss. The goal for this project was to do it fast and not to further optimize the method because of the already small amount of measurements.

This method is planned to be further optimized in the Ranstad decommissioning project where a reduction in measurement time is a great gain.

The 2044 ton ship m/s Sigyn was cleared for free use with less than 1200 scintillation measurements and has been decommissioned during the summer of 2015.

This method for nuclide inventory and clearance level calculations can be used in every major decommissioning project and it will most likely save a lot of measurement time, especially if the method is further optimized.

REFERENCES

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