History of radiological characterisation in decommissioning projects in Studsvik

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Introduction

AB SVAFO is a nuclear waste technology and decommissioning company based in Sweden in the scenic surroundings of Studsvik on the Baltic coast. SVAFO is owned by the Swedish nuclear power industry. The company was created in 1992 by Sydsvenska Värmekraft AB, Vattenfall AB, Forsmarks Kraftgrupp AB and Oskarshamns Kraftgrupp AB as a consequence of the Act on the Financing of the Management of Certain Radioactive Waste, etc. from 1988.

AB SVAFO's main business is to take care of formerly state-owned spent nuclear waste at the site, including small amounts of nuclear fuel. Buildings are also included, mainly nuclear waste storage buildings and a research reactor. Some buildings have already been decommissioned and all the fuel has been treated.

In the past 30 years, various decommissioning projects have been carried out, encompassing areas such as an underground research reactor, a Van de Graaff accelerator, a purification plant, 15,000 m^2 of nuclear laboratories, two 150 m^3 underground concrete sludge silos and several waste-storage buildings [Hedvall et al, 2009; Hedvall, 2010].

Until now, only one or two people in the presented decommissioning projects were involved in the characterisation to determine the level of contamination before the actual work began. With the start of the decommissioning of the former uranium mine in Ranstad and the Ågesta and R2 reactors, more effort will be made on characterisation.

In the 1990s, regulations requiring smaller releases of nuclear waste from nuclear installations for deposit at city dumps (SSI FS 1996:2) set limits of 40 kBq/m^2 for beta and gamma radiation and 4 kBq/m^2 for alpha for surface contamination and 5 kBq/kg (0.5 kBq/kg for alpha) for specific activity. Free release (clearance) of tools and other equipment was allowed if testing revealed contamination of less than 0.5 kBq/kg (0.1 kBq/kg). Total annual disposed activity in a municipal dump for radioactive waste from Studsvik with an activity of less than 5 kBq/kg was limited to 1 GBq/year.

At the end of the last century, smear tests were used on all surfaces. The limit applied to free release was 4 kBq/m^2 (gamma, beta) and 0.4 kBq/m^2 (alpha). One smear sample was taken on every square metre of flooring and walls up to a height of 2 m. Above that and on ceiling areas, only spot-checks were taken. Dose rate measurements were performed where smear tests were taken. Gamma spectrometry was performed on one sample or smear test in every room [Andersson, 1998].

Clearance of material and oil regulated by general
SSI Regulations from 1996 (SSI FS 1996:2) (not intended for large amounts of material) and by specific approvals (for example recycling of metals and PVC) followed a general activity limit of 500 Bq/kg (gamma, beta) and 100 Bq/kg (alpha) activity.

Release limits have changed from a single value of 8 kBq/m^2 in 1980 to different nuclide-specific limits in 2012 and much more extensive efforts for characterisation are now done on all surfaces. Gamma spectrometry now covers all surfaces.

Whereas a few hundred smear measurements were previously taken in smaller projects, hundreds of thousands of measurements are now performed.

The decommissioning projects

Underground research reactor (R1)

Sweden's first nuclear reactor, in operation from 1954, was located in Stockholm. It was closed down in 1970 and decommissioned between 1979 and 1983. Expenses were underestimated, but the overall project was a success financially and technically and the timetable was followed almost as planned. The cost for the four years was SEK 25 million, not including low and medium-level material stored at SVAFO or the processing of the fuel. The graphite reflector was decommissioned by eight people, receiving 49 mpersonSv, and the biological shield was demolished by 15 people (16 mpersonSv). In total, there were 25 people in the project (142 mpersonSv). For transports, 16 people were involved and the radiological survey was done by four people [Andersson et al, 2006].

The pre-characterisation in 1979 was performed by dose rate measurements in channels, the ventilation system, tubing and graphite. Gamma spectrometry was done by a silicon detector (17% HPGE). Samples from the concrete were taken by drilling holes [Menon et al., 1979]. Suggested limits for free release were 70 kBq/kg for materials, 4 kBq/m^2 for surface contamination and 7 MBq/m^3 for liquid waste [Menon et al., 1980], but the accepted limits later on were 5 kBq/kg for concrete for shallow land deposit at the Studsvik site and 1 MBq/m^3 for release to municipal dump. The limit for release to unrestricted use was set by the authorities to 8 kBq/m^2 [Kärker et al., 1985]. This limit was specified for this project only.

One smear test (beta) was taken from every square metre of flooring and walls up to a height of 2 m. Above that and in the ceilings, one sample was taken every ten square metres. Gamma spectrometry was performed on a batch of samples from each room.

Van de Graaff (VdG)

The pre-decommissioning with cleaning up of the accelerator and characterisation was done between 1990 and 1997 with a small group of workers. For the characterisation in 1990, 100 samples were taken [Bengtsson & Pettersson, 1991]. For the last three-month period, the

decommissioning project had one radiation protection officer for measurements and two cleaners working full time [Chyssler, 1995]. The total cost of the project was approximately SEK 3 million (SEK 0.6 million for the demolition).

The project proposed a free release limit of 500 Bq/m^2 for tritium, 40 Bq/m^2 for beta/gamma and 4 Bq/m^2 for alpha contamination. One smear sample for tritium and one smear sample for alpha/beta was taken for every 9 m^2. The total wall, ceiling and floor surface was 3000 m^2 so approximately 350 samples each were taken [Chyssler, 1995]. The size of the floor surface for one smear sample was changed from 3 x 3 to 1.5 x 1.5 m^2. All surfaces and materials were checked for alpha and beta/gamma with a portable contamination meter of Type P.C.M. 5/1 [Chyssler, 1998].

Purification plant (Ågesta)

The purification plant was used for the treatment of liquid and gaseous waste from the first Swedish nuclear plant. The nuclear plant was closed down in 1974. Its size was less than 1000 m^2.

Characterisation was performed in 1995 (for SEK 63,000) and 1996. In 1995, the limit for free release was set to 5 kBq/m^2 (gamma, beta) and 0.5 kBq/m^2 (alpha). For tritium and C-14, the limit was set to 500 kBq/m^2 in 1997 when the liquid scintillation technique was used. Alpha and beta/gamma were measured directly with the Nuclear Enterprise PCM 5 with detector DP2R. Tritium was measured with the Scintrex 209K. Indirect smear samples (approximately 1000 samples) were measured with the Berthold LB 770 instrument. The floor was divided into 1 m^2-squares and walls and ceilings into 4 m^2-squares where one smear sample in each square was taken [Hedlund & Serby, 1995]. More measurements (approximately 50 samples) were performed in 1996 when a Ge-detector was also used [Pettersson, 1996].

Nuclear Laboratory (ACL)

This involved a six-year decommissioning project comprising an 18,000 m^2 nuclear laboratory [Hedvall *et al.,* 2006]. A simple characterisation was performed by one person in 1998. In situ gamma measurements were taken by two people responsible for the practical measurements and one radiation physicist was responsible for the calculations as a final check after the decontamination. The intention was to save 50% of the smear tests. The total cost of the project was almost SEK 80 million [Ellmark et al., 2007]. No personal radiation doses were measured.

The decommissioning project began by removing all loose equipment. A first cleaning was performed before the first characterisation prior to the planning of decommissioning methods. It was then decided to remove tubes for waste and ventilation, tanks and every type of installation except main electricity. Control of radioactive emissions was performed during the project. Vacuum cleaning was used before and after cleaning and removal of hot spots in concrete. To remove contamination, alcohol or a pressure washer was used. Reciprocating saw and grinders were also used.

Smear tests were used on all surfaces. The working limit for free release was 4 kBq/m^2 (gamma, beta) and 0.4 kBq/m^2 (alpha). In the laboratories, one smear sample was taken on every square metre of floors and walls to a height of 2 m and 100% hand monitoring was applied. Above that

and on the ceiling, one sample was taken for every 4 m^2. Dose rate measurements with the Mini 1500 instruments with probe DP6AD were used on all surfaces. As a complementary check, 6-hour gamma spectrometry measurements with ISOCS-technique were used.

A summary shows that 41,000 smear tests were taken, 39,000 m^2 was monitored by hand and 37,000 m^2 was covered with gamma spectrometry. The total surface area was 52,000 m^2 [Ellmark, 2005].

Table I. Specific decommissioning clearance levels for ACL

Nuclide	Activity (kBq/m^2)
Co-60	10
Cs-134, 137	100
Sr -90	1,000
H-3	100,000
Pu-238, 239, 240, 242	10
Am-241	10
Pu-241	1,000

Conclusions

Release limits have changed from a single value of 8 kBq/m^2 in 1980 to different nuclide-specific limits in 2012, and much more extensive efforts for characterisation are now done on all surfaces. Gamma spectrometry now covers all surfaces.

From a few hundred smear tests in smaller projects, hundreds of thousands of measurements are now performed and complemented with sophisticated gamma spectrometry methods and mathematical statistic decisions.

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