General data in accordance with the requirements in article 37 of the Euratom Treaty

Dismantling of the nuclear reactors Oskarshamn 1 and 2 in Sweden

11th May 2017

About this report

The present document has been compiled and completed by the Swedish Radiation Safety Authority (SSM), mainly based on information provided by the license holder, OKG AB. The purpose of the document is to serve as information for the European Commission, and to fulfil the requirements of Article 37 of the Euratom Treaty. SSM has controlled that the general data provides the necessary information and that it follows the guideline in annex 3 of the recommendation of the application of Article 37 of the Euratom Treaty 2010/635/Euratom. The report has been approved by the Head of Section Ove Nilsson and has been registered by the authority with document number SSM20017-333-2. On the 11th of May 2017 SSM approved to submit the report to the Swedish Government in order to be submitted to the European Commission.

Summary

The recommendation of the European Commission of 11 October 2010 on the application of Article 37 of the Euratom Treaty (2010/635/Euratom) requires each member state to provide the Commission with general data related to for instance dismantling of nuclear reactors, which will make it possible to determine whether the implementation of the activities is likely to result in radioactive contamination of the water, soil or airspace of another member state.

This report describes the consequences of decommissioning two boiling water reactors and the common waste handling building at the Oskarshamn Nuclear Power Plant. The two reactors are designed and built by ASEA-Atom. Oskarshamn 1 (492 MWe) commissioned in 1972, and Oskarshamn 2 (661 MWe) commissioned in 1975.

The presented information regarding radioactive discharges to air or water at normal decommissioning operation or unplanned events during decommissioning indicates that there will be no releases that will give measurable dose levels in other member states.

If the assessed maximum exposure levels from discharges during normal conditions to adults, children and infants in the vicinity of the plant are below 0.01 mSv per year and there are no exceptional pathways of exposure, e.g. involving the export of foodstuff, no data on effective dose in other affected member states are required if doses to the reference group in the vicinity of the plant are provided.

The doses to the reference group in the vicinity of the plant during the dismantling and demolition phase are estimated to be less than 0.000006 mSv, i.e. the year when the dose is at its maximum during segmentation of reactor internals. The calculated discharges of Co-60 to air are more than a factor 1,000 less than what would be allowed and still give a dose to the reference group below 0.01 mSv. The discharges to air give higher dose than the discharges to water.

The doses to the reference group are well below the specified limits. Any data on effective dose in other affected member states are thus not required.

Data used in the calculations have been chosen to ensure that the results are not underestimating the discharges and doses.

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0 Introduction

The purpose of this report is to provide the Commission with general data relating to the decommissioning of the two nuclear reactors, Oskarshamn 1 (O1) and Oskarshamn 2 (O2) and the common waste handling building (0AVF) at the Oskarshamn Nuclear Power Plant (NPP). The results will make it possible to determine whether the implementation of the plans is liable to result in the radioactive contamination of the water, soil or airspace of another European Union Member state. The report follows the guideline in annex 3 of the recommendation of the application of Article 37 of the Euratom Treaty (2010/635/Euratom) [1].

In order to start dismantling and demolition of nuclear power plants in Sweden, acceptance is required in accordance with Article 37 of the Euratom Treaty [1] and approval by the Swedish regulatory body SSM (Swedish Radiation Safety Authority) and license from the Land and Environmental Court in Sweden.

During the decommissioning phase it is the responsibility of the holder of the nuclear licence to dismantle and demolish the whole or parts of the facility, to reduce the amount of radioactivity in soil and remaining buildings to levels possible to enable clearance of the site around the facility.

The most common definitions and abbreviations used in this report are given in appendix 1.

Oskarshamn Nuclear Power Plant

The Oskarshamn nuclear power plant is owned and operated by OKG AB which is also the holder of the nuclear licence to operate and decommission the plant. OKG AB is jointly owned by Uniper which owns 54.5 % and Fortum which owns 45.5 % of the company.

Oskarshamn NPP is located in southern Sweden, on the east coast approximately 350 km south of Stockholm and about 20 km north of the town of Oskarshamn with approximately 20,000 inhabitants.

The three boiling water reactors, BWR, are designed and constructed by ASEA-ATOM. Oskarshamn 1 (492 MWe) commenced operation in 1972 and Oskarshamn 2 (661 MWe) commenced operation in 1975. The third and largest reactor Oskarshamn 3 (1450 MWe) commenced operation in 1985 and is planned to continue its operation until 2045.

The present situation at the time of this report being issued, is that Oskarshamn 1 is still in power operation and will be until the end of June 2017. In 2013, Oskarshamn 2 was scheduled for a safety and power upgrade. The installation started but before the unit was again synchronized to the grid, it was decided not to restart the operation. The decision to decommission Oskarshamn 2 was taken in 2015. At the same time, it was decided to decommission Oskarshamn 1.

The spent fuel removal is performed on a regular basis at all Swedish NPPs. The spent fuel will be removed off-site to the interim storage at the Central Interim Storage Facility for Spent Nuclear Fuel (Clab), owned and operated by the Swedish Nuclear Fuel and Waste Management Company (SKB) before the dismantling activities start. Clab is the facility used by all NPPs in Sweden for storage of spent fuel and it is located at the same site as the Oskarshamn NPP. An overview of the Swedish system for handling of spent fuel and nuclear waste is described in detail in appendix 3.

The decommissioning described in this report includes Oskarshamn 1 and 2 and the common waste handling building (0AVF). Additionally, demolition of non-contaminated buildings such as electrical buildings will also take place. The waste handling building will remain in operation during the decommissioning of Oskarshamn 1 and 2 and will be demolished after Oskarshamn 1 and 2 have been demolished.

Decommissioning licensing

In order to receive the required licenses for decommissioning, a licensing process is run at the Land and Environmental Court in Sweden (see figure 0-1). The Swedish Radiation Safety Authority (SSM) participates in this process. The updated Safety Analysis Report for decommissioning (SAR) need to be approved by SSM prior the beginning of the decommissioning activities.

According to Swedish law it is the owners of the nuclear power plants that have to pay for all the costs of dealing with spent nuclear fuel and its final disposal. They also have to pay the costs of decommissioning of nuclear power plants and other nuclear installations. Since the mid-1970s the nuclear power operators have been allocating funds to cover these costs. These funds are administered by the Nuclear Waste Fund. SKB conducts regular calculations of the future costs for dealing with nuclear waste and submits the updated budget to the Swedish Radiation Safety Authority every three years. After the calculations have been reviewed, the authority then proposes the surcharge for the next few years to the Government, which decides on the amount to be charged.

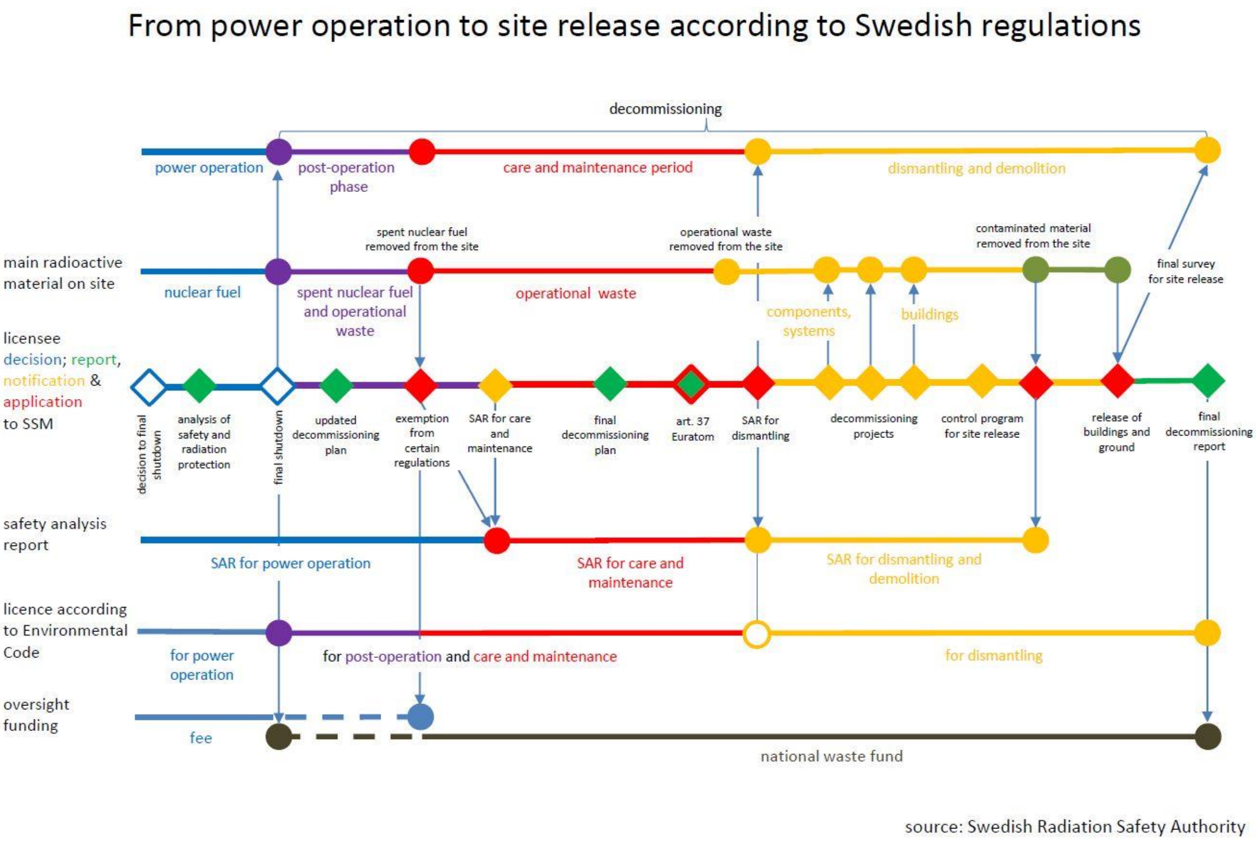

Figure 0-1. The picture presents the decommissioning process including the procedures for approval and licensing.

Swedish Radiation Safety Authority - SSM

The Swedish Radiation Safety Authority (SSM) reports to the Ministry of the Environment and Energy and has a mandate from the Swedish Government within the areas of nuclear safety, radiation protection and nuclear non-proliferation.

The authority works proactively and preventively in order to protect people and the environment from the undesirable effects of radiation.

The Act on Nuclear Activities 1984:3, the Radiation Protection Act 1988:220 and Ordinance 2008:452 with instructions for the Swedish Radiation Safety Authority have been translated into English and can be found on the SSM website (www.ssm.se). These acts and ordinance, together with the Ordinance on nuclear activities 1984:14 and the Radiation Protection Ordinance 1988:293, stipulate the boundaries for all nuclear activities in Sweden. SSM has developed regulations (SSMFS) to give a more detailed framework for e.g. nuclear power plants. Some of the regulations are available in English.

In order to start the decommissioning and dismantling, a safety analysis report (SAR) must be approved by SSM. The requirement to have an approved SAR is found in SSMFS 2008:1 [12], which is part of the Swedish Radiation Safety Authority regulations. The regulations in SSMFS 2008:1 apply to measures required to maintain safety in connection with the construction, possession and operation of nuclear facilities with the aim of, as far as reasonably achievable, taking into account the best available technology, preventing radiological accidents and preventing the unlawful handling of nuclear material and nuclear waste. The regulations comprise provisions on technical, organisational and administrative measures. Chapter 9 in SSMFS 2008:1 stipulates the requirement for decommissioning and dismantling.

The decommissioning process is described in a decommissioning plan. For a NPP with more than one unit, it is also required that a decommissioning strategy is produced, describing the decommissioning process on a comprehensive level for the entire NPP site. The decommissioning strategy and plan are required by SSM, as well as the waste management plan and must be reviewed and accepted together with the safety analysis report by the authority in order to be granted an approval for dismantling and demolition activities.

After acceptance of the Safety Analysis Report (SAR), each dismantling and/demolition package/project of parts (components, systems or building) of the plant that contains contaminated or activated systems must be notified to SSM. The size of each package/project is up to a licensee to decide. SSM conducts regular oversight activities according to graded approach principle during the entire decommissioning and dismantling process.

The site will be released from the regulatory control from the Act on Nuclear Activites by the Governmental decision, upon the recommendation of SSM once the final state report is approved.

Environmental impact assessment

The operator must also apply for a license in accordance with the Swedish Environmental Code in order to decommission a nuclear plant/unit. The Swedish Environmental Protection Agency, Swedish EPA, the County Administrative Board (CAB), the local Environmental and Public Health Committee and the Swedish Radiation Safety Authority (SSM) are consulted in the licensing procedure and are given the opportunity to propose specific licensing conditions.

In order to obtain a complete set of licenses for the process described in this report, three different applications must be handed in to the regional Land and Environmental Court in Sweden; one application for Oskarshamn 1 for the Post-operation and Care and Maintenance period, which has already been accepted by the Land and Environmental Court in Sweden, one application for Oskarshamn 2 for the Post-operation and Care and Maintenance period, this application process is ongoing and OKG expects to receive a licence by mid-2017. Finally, an application is also required for the dismantling and demolition of Oskarshamn 1 and 2 and the common waste handling building (0AVF). This process has recently been initiated, and an open public hearing has been held. Work is in progress to prepare the application in accordance with comments from the stakeholders.

The County Administrative Board and the local Municipality have their terms and conditions that require formal approval. These include, for instance, handling of chemicals and handling of conventional and hazardous waste. A demolition permit from the local Municipality in accordance with the Planning and Building Act (2010:900) is required for the conventional demolition of the buildings.

Decommissioning planning

Figures 0-2 and 0-3 show an overview of the decommissioning planning.

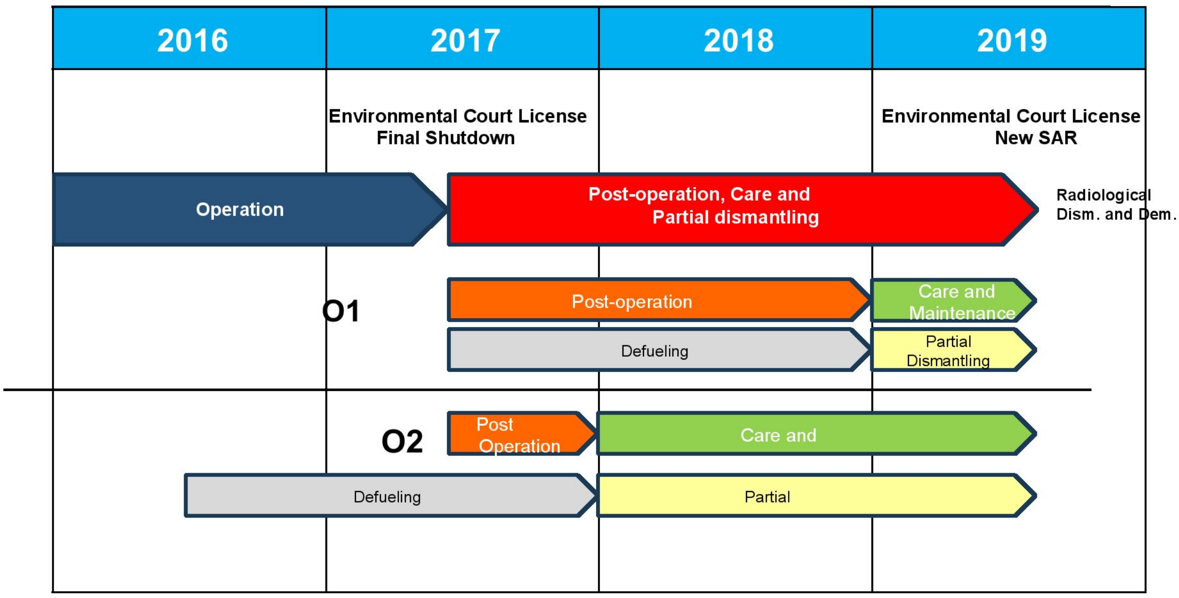

Figure 0-2. Overview of Planning for Decommissioning until 2019.

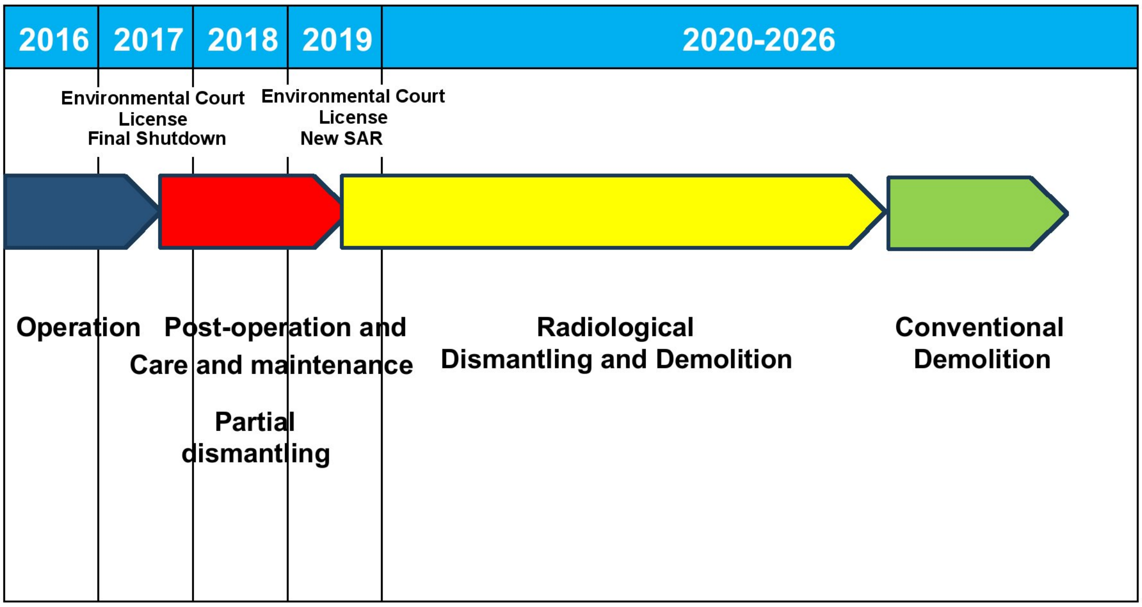

Figure 0-3. Overview of Planning for the whole Decommissioning process until Conventional demolition.

Project planning for the decommissioning, dismantling and demolition phases of Oskarshamn 1 and 2 began in late 2015/early 2016, see figure 0-3. The first phase includes identification and submission of documents in order to obtain necessary licences from the regulatory bodies for the final dismantling and demolition of Oskarshamn 1 and 2 and the common waste handling building (0AVF). The first phase also includes general project planning, preparatory work and radiological characterisation.

An important part of the planning process in order to identify the most efficient dismantling, demolition and waste handling logistics is the guidance regarding radiological characterisation given in the report from OECD/NEA (Nuclear Energy Agency), [3]. Data collection, historical as well as current, is ongoing and will continue during the dismantling when new areas become accessible.

The plan is to dismantle the two nuclear power plants in parallel. Work will be in progress at both Oskarshamn 1 and 2 but not necessarily similar work at the same time. The reactors Oskarshamn 1 and 2 are connected via electrical buildings, control rooms and personnel buildings. The plan is to dismantle the radioactive parts in approximately 5-7 years. In order to reduce the level of radioactivity, create a safe environment and have a more accessible facility, it is planned to start the dismantling process by removing and segmenting the internal parts of the reactors. The plan is to start the segmentation at Oskarshamn 2 in 2018, and for Oskarshamn 1 in 2019. Another activity concerns preparing the turbine building at Oskarshamn 2 for waste logistics.

The different dismantling packages/projects are described in table 0-1. The main focus is to reduce the level of radioactivity early in the process. However in order to do so it will be necessary to remove non radioactive parts to avoid cross contamination.

Table 0-4. Overall schedule for dismantling and demolition activities.

Year	Dismantling and demolition schedule
2018	O2 Segmentation of reactor internals
2019	O1 Segmentation of reactor internals
2019	O2 Full scale chemical decontamination
2020	O1 Full scale chemical decontamination
2020	O2 Reactor vessel
2020	O2 Reactor hall
2020	O2 Containment
2020-2021	O2 Turbine building
2020-2021	O1 Turbine building
2020-2023	O2 Reactor building
2021	O2 Biological shield
2021	O1 Reactor vessel
2021	O1 Reactor hall
2021	O1 Containment
2021-2024	O1 Reactor building
2022	O1 Biological shield
2025-2026	Waste handling building

Radiological clearance will continue for 1-2 years after the dismantling and demolition are finished.

Once the fuel has been removed, the reactor internals are likely to constitute the next significant contributor to the radiological inventory of the site. The reduction in site radiological inventory offered by removal of the fuel and early removal of the internals significantly reduces the total radiological hazard present on site.

Based on the above, it is therefore proposed that the reactor internals are the first major dismantling activity to be carried out inside the Reactor Building, and will be carried out after a pre-decommissioning decontamination of the primary systems in order to reduce worker doses incurred during the dismantling tasks. Following the removal of the internals, work will continue on other tasks within the reactor and turbine buildings.

The resulting overall dismantling sequence will be developed further during the decommissioning planning.

If necessary, contaminated soil must be treated before clearance of the ground for the intended future use can be approved. At present the site is intended for industrial use, also called “brown field”.

The waste handling is described in section 5 in this report. In order to optimize the process, several options are available. There are two possible end-states in Sweden for radioactive material and waste, clearance (also referred to as “free release”), either general or conditional, or disposal of solid radioactive waste and material. Disposal of solid waste and material can be done in landfill for very low level active waste. There is also a central final, geological, repository for short-lived low and intermediate level radioactive waste (SFR). In the future there will also be a central final, geological, repository for long-lived low and intermediate level active waste (SFL). See appendix 3 for more details.

Estimated dose from discharges to air and water

Co-60 has been used as the base in all calculation in this report. It is at present the dominating nuclide in all discharges from Oskarshamn 2 since it was shut down in 2013 and the short-lived nuclides have decayed. In Oskarshamn 1 there will be some short-lived nuclides as well, but they will not result in significant dose to the reference group. The assumptions are described in more detail in section 3.

Discharges to air will give higher dose to the reference group than discharges to water, approximately a factor of 10 more. The total dose for infants 1-2 years, children 7-12 years and adults are shown in figure 0-4. Dose factors based on reports from Studsvik in 2002 [25-31] are described in section 3.4.

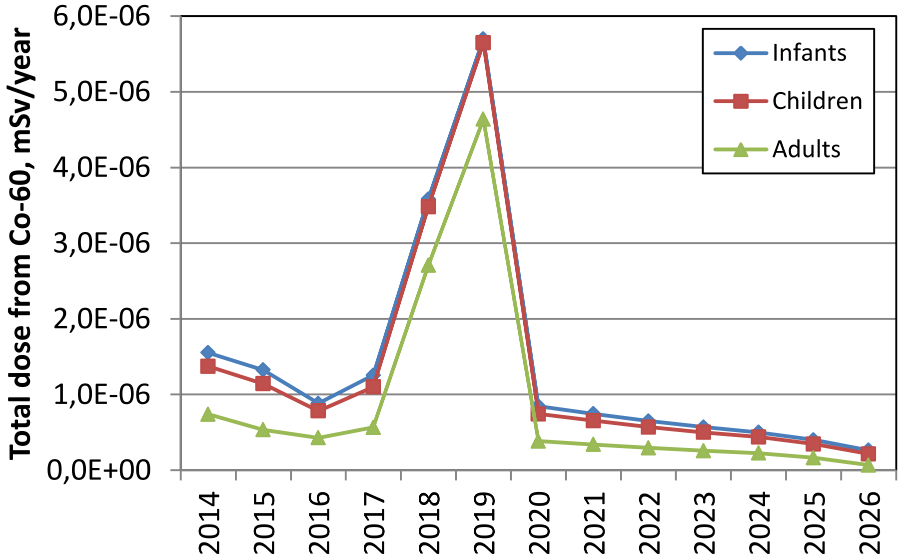

Figure 0-4. Total dose from Co-60 in discharges to air and water from the decommissioning of Oskarshamn 1 and 2. The peak in dose is due to segmentation of reactor internals.

If the assessed maximum exposure levels from discharges during normal conditions to adults, children and infants in the vicinity of the plant are below 0.01 mSv per year and there are no exceptional pathways of exposure, e.g. involving the export of foodstuff, no data on effective dose in other affected member states are required if doses to the reference group in the vicinity of the plant are provided.

The doses to the reference group are well below the specified limits. Any data on effective dose in other affected member states are thus not required.

1 The Site and its Surroundings

1.1 Geographical, Topographical and Geological Features of the Site and Region

The Oskarshamn nuclear power plant is located on the east coast in the southern part of Sweden, see figures 1-1 and 1-2.

Figure 1-1. The location of Oskarshamn NPP (Bing Maps).

Oskarshamn NPP is not located at a close distance to any other member state, the nearest one is Denmark with a distance of 260 km. The distances to the closest neighbouring member states are shown in table 1-1.

Table 1-1. Oskarshamn NPP neighbouring states. (Bing maps)

Country	Distance to border (km)	Metropolitan area	Population (millions)	Distance to metropolitan area (km)
Denmark	260	Copenhagen	2.0	320
Latvia	270	Riga	0.7	450
Estonia	320	Tallinn	0.6	520
Germany	360	Berlin	4.4	580
Finland	350	Helsinki	1.1	570
Lithuania	310	Vilnius	0.6	610
Poland	300	Warsaw	3.2	640

Figure 1-2. The location of Oskarshamn nuclear power plant (Lantmäteriet maps).

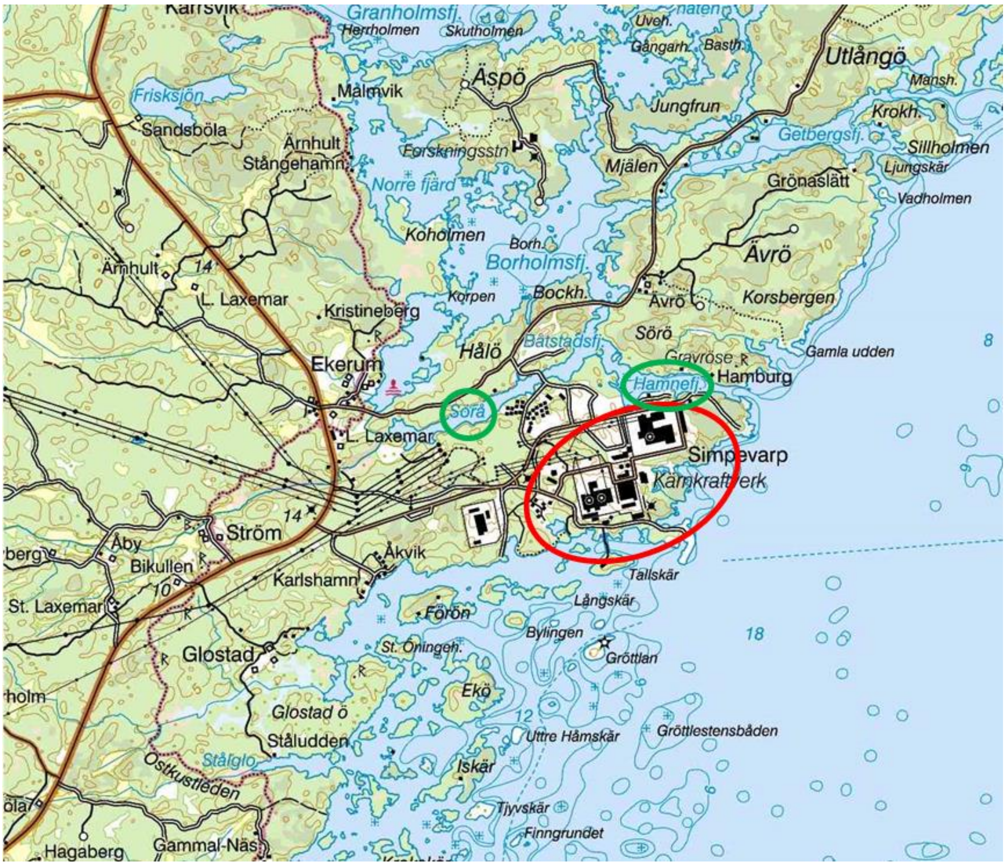

Figure 1-3. Oskarshamn NPP is in the red circle and the cooling water outlet in the right green circle, Hamnefjärden.

The Oskarshamn Nuclear Power Plant (NPP) is situated by the Baltic Sea in the municipality of Oskarshamn on a peninsula called Simpevarp, 8 km north-east of the village of Figeholm and 20 km north-east of the town of Oskarshamn, the coordinates of which are 57°25'N 16°40'E according to WGS84 (the World Geodetic System 1984). See figure 1-3.

Other nearby nuclear installations are:

- Oskarshamn 3, a boiling water type reactor which is currently in operation. The reactor has an electric power of 1,450 MWe. Oskarshamn 3 is situated on the Simpevarp peninsula approximately 500 metres north-east of Oskarshamn 1 and 2.
- The Central Interim Storage Facility for Spent Nuclear Fuel (Clab) is situated 700 metres west of Oskarshamn 1 and 2. Clab is owned and operated by SKB and licensed by the Swedish Government (see appendix 3).

The soil layer in the area is thin and therefore exposed rock is very widespread on the surface. The surface of the rock has eroded and been reshaped by the glacial ice. Till is the most common type of soil. The height differences in the area are small. Large areas around the site have been greatly changed by blasting, excavation, filling or other forms of foundation work. The ground at the site of the Simpevarp peninsula is dominated by two different categories of bedrock. One type of bedrock is a granite type called “Smålandsgranit”. The other type is Dioritoid, a metamorphic volcanic type that consists of different small rock granules that varies in colour from grey to grey black. The rock Dioritoid has often been recrystallized to a more granite like rock. This is especially valid for the bedrock at Simpevarp, see figure 1-4. The bedrock at Simpevarp differs from the surrounding areas which are mostly granite. The bedrock in the area was created approximately 1,800 million years ago from volcanic activity.

Figure 1-4. The types of bedrock and deformation zones. Green areas consist of Dioritoid and red consist of Smålandsgranit. The deformation zones are given in red lines or black dashed lines (figure from OKG report 2010-07329 [4]).

1.2 Hydrology

The Simpevarp area consists of solid bedrock with some deformation zones and with very low ground water flow [5]. Extensive research of the bedrock has been carried out in cooperation with SKB as part of the siting process for the final repository for spent fuel. The investigated area includes the area below the Simpvarp peninsula. The level of groundwater follows mainly the topography and is close to ground level. Around buildings that are partly or wholly under ground, groundwater is drained continuously, causing a local impact.

The fresh water supply for Oskarshamn NPP comes from the lake Götemaren that is situated 8 km north-west of the location of Simpevarp.

The intake of cooling water from the Baltic Sea for all units on site is situated on the south side of the peninsula, Oskarshamn 1 and 2 have the possibility to take cooling water from a deep sea water intake, or surface water. The outlet for all units on site is on the north side, see figure 1-5, 1-6 and 1-7. Since Hamnefjärden is a narrow coastal inlet, the flow rate of the discharged cooling water is locally strong. The flow rate of the outlet water then decreases rapidly as the flow enters the Baltic Sea after 800 metres. During normal operating conditions at Oskarshamn 3, the cooling water is heated about 10 ºC.

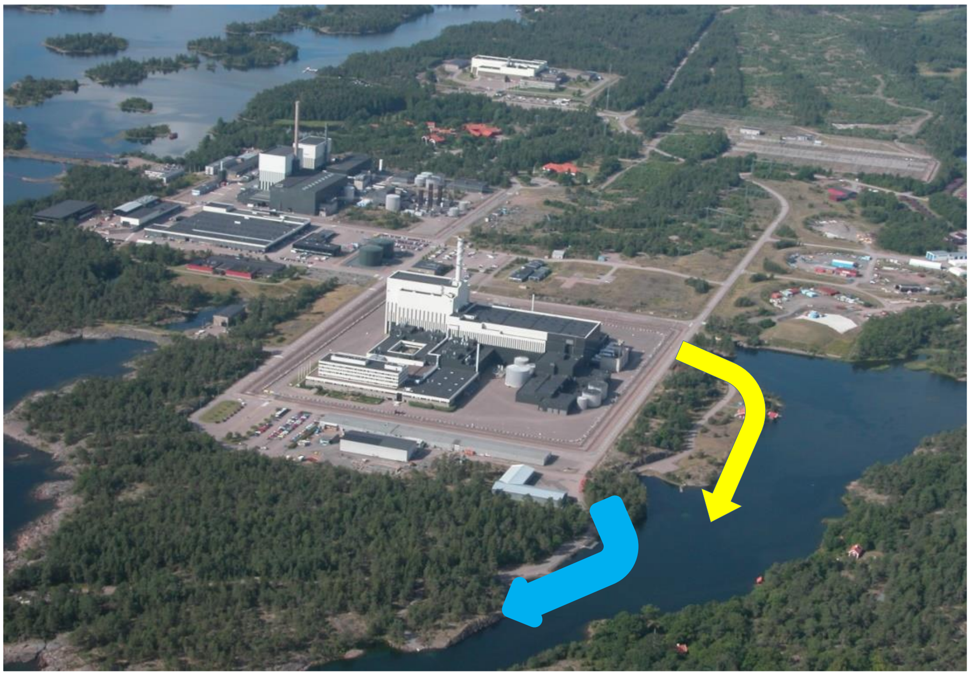

Figure 1-5. Oskarshamn NPP with the cooling water outlet for unit Oskarshamn 1 and 2 in yellow and for Oskarshamn 3 in blue. The outlet into Hamnefjärden is on the north side of the Simpevarp peninsula.

Figure 1-6. Cooling water outlet to Hamnefjärden, the left blue arrow is for Oskarshamn 1 and 2 and the right one is for Oskarshamn 3 (Lantmäteriet maps).

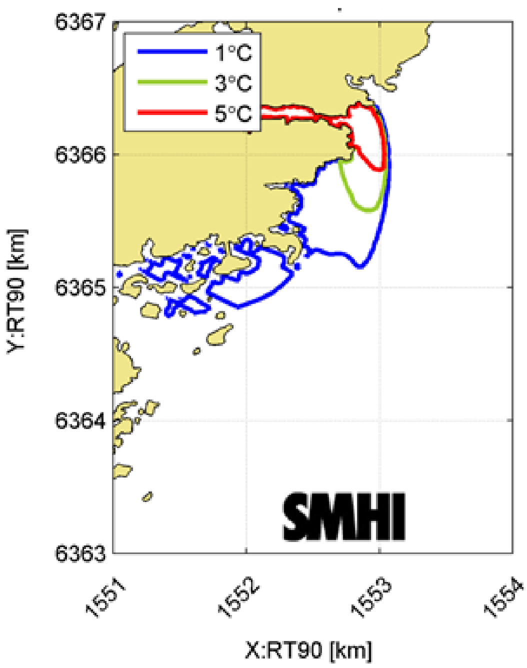

Figure 1-7. The plume of heated cooling water spread in the surface water with the conditions: In the month of April, southbound water stream 15 cm/s, north-easterly wind 5 m/s, Oskarshamn 1 and 2 not in operation, normal operation at Oskarshamn 3 and use of deep sea water intake for all units. The figure also corresponds with how the spread of discharge with the water to the sea is during one type of conditions (figure from report SMHI 2016-23 [6]).

Just outside the location at the Simpevarp peninsula, there is open sea water. The littoral area to the north and south consists of a lot of small islands and a coast line that is full of small fjords, coves and bays.

The Baltic Sea is a brackish sea with limited water exchange. There are no river tributaries within 10 km from Simpevarp. There is hardly any tide water in the Baltic Sea. In the southern part of the Baltic Sea, the tide can be a few centimetres.

The rotation of the earth leads to a weak anticlockwise circular flow of the water in the Baltic Sea. The most significant factor affecting the flow is the wind direction. Typical flow rate is 0.1 m/s and for shorter periods up to 0.5 m/s. The current outside Oskarshamn NPP flows north 55 % of the time and south the other 45 % of the time (according to measurements performed during 1975 to 1976). This is due to the two large Swedish islands, Öland and Gotland, which are situated off shore from Oskarshamn NPP. These islands force the current to go north or south, the flow is more likely to follow along the Swedish coast line than to flow easterly directly towards the other side of the Baltic Sea, see figure 1-1 and 1-2.

The area around the power plant is not sensitive to flooding because there are not any large watercourses within 10 km in either direction, and the land is relatively high in relation to the sea level, see figure 1-8. The area can also withstand heavy rain without flooding occurring, see figure 1-9.

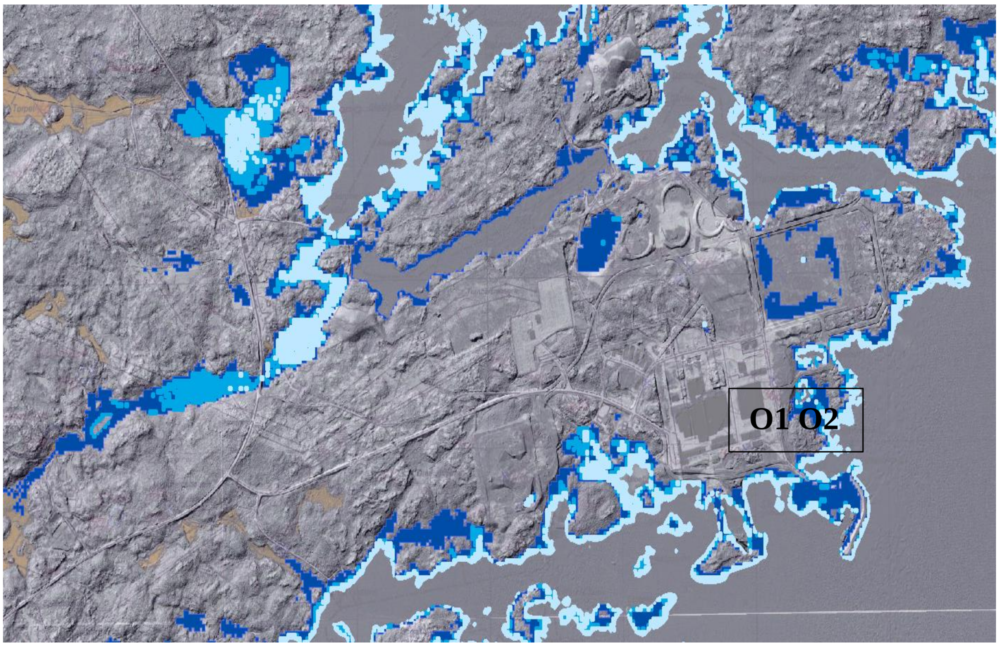

Figure 1-8. Height map showing flooded area with 1, 2 and 3 meter water rise marked from light- to dark blue (County Administration Board).

Oskarshamn 1 and 2 and their waste handling building are situated six metres above the median sea level and the calculated highest level during a period of 100 years is 1.18 metres above the median. This gives a good margin for the plants to withstand any high sea water (see table 1-2).

Table 1-2. Highest reported and calculated levels for the area around Simpevarp [7].

Average level, annual highest	Highest reported level in 45 years	Calculated maximum level in 100 years	Calculated maximum level in 1000 years
68 cm	101 cm	118 cm	146 cm

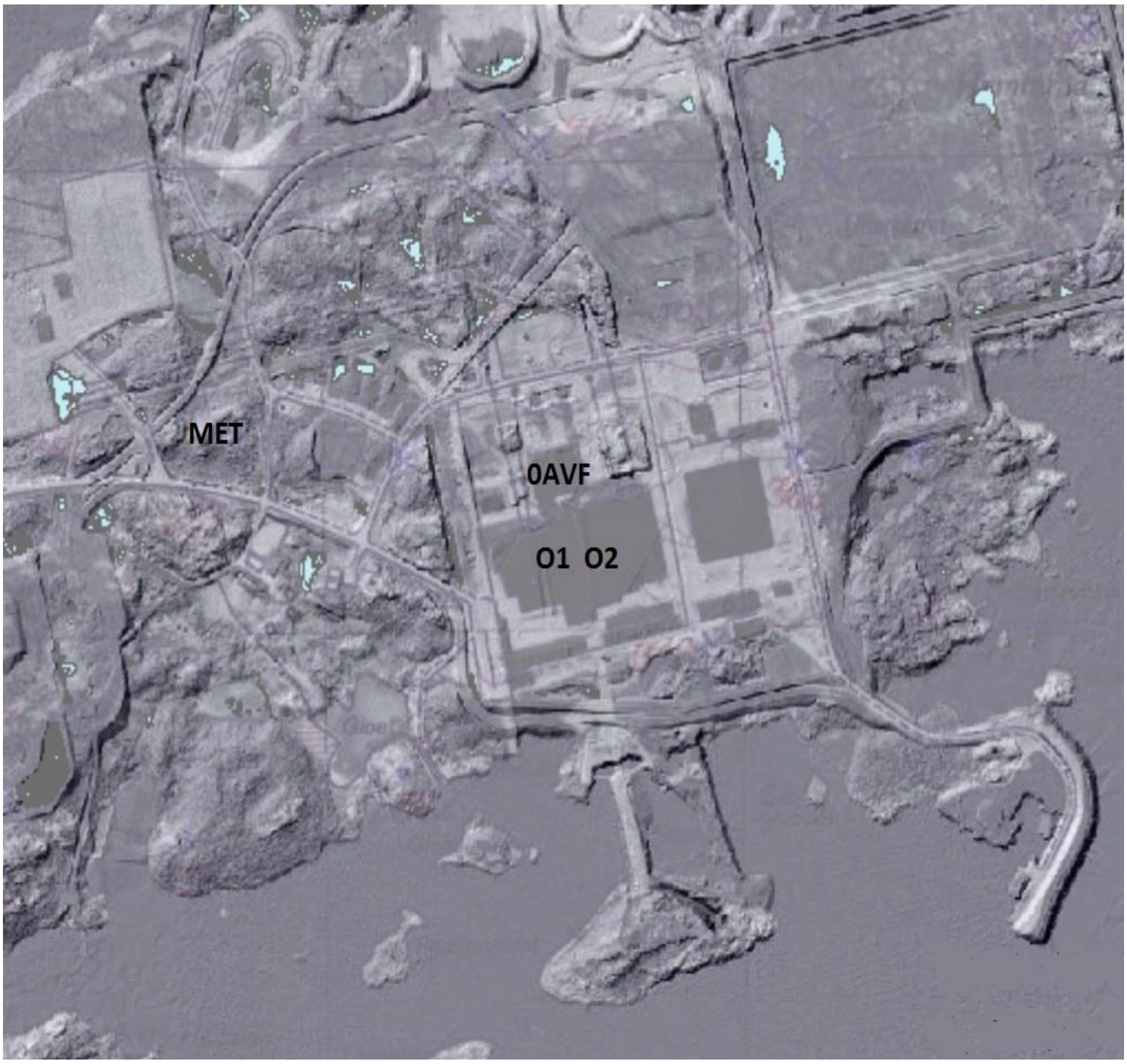

Figure 1-9. The light blue areas are enclosed (0.25 – 0.50 meter) and these are areas where water can remain after a heavy rainfall (County Administration Board).

1.3 Meteorology

Meteorological measurements

A local meteorology mast (MET, see figure 1-2 and 1-9) collects weather data. It has the ability to measure temperature, atmospheric pressure, wind speed and direction at three different levels, 2, 10 and 100 metres (before year 2014 these levels were at 25, 70, and 100 metres) from the reference level +110.0 (10 meters above sea level). One purpose with the local meteorology mast is to be able to obtain data for calculations of radioactive releases following an initiating event. The mast is situated on the Simpevarp peninsula close to Oskarshamn 1 and Oskarshamn 2.

Meteorological data for the site is supplemented and evaluated based on data from nearby meteorological stations. These stations are situated 22 km south-west of the town Oskarshamn, 38 km north of Västervik, 85 km south of Kalmar and at the northern tip of the island Öland, 25 km east of the site. These nearby stations have relevant data for the weather conditions on the site and have longer measurement series.

Some results of the temperatures measured in Oskarshamn during the period 1961-2006 are shown in table 1-3.

Table 1-3. Measured temperatures in Oskarshamn during the period 1961-2006

Highest measured temperature	Lowest measured temperature	Highest average temperature is during the month of July	Lowest average temperature is during the month of February
33,2 °C	-34,6 °C	16,5 °C	-2,5 °C

Wind

The most common wind direction is from the southwest. Average wind speed is between 3 and 4 m/s. See figures 1-10 and 1-11.

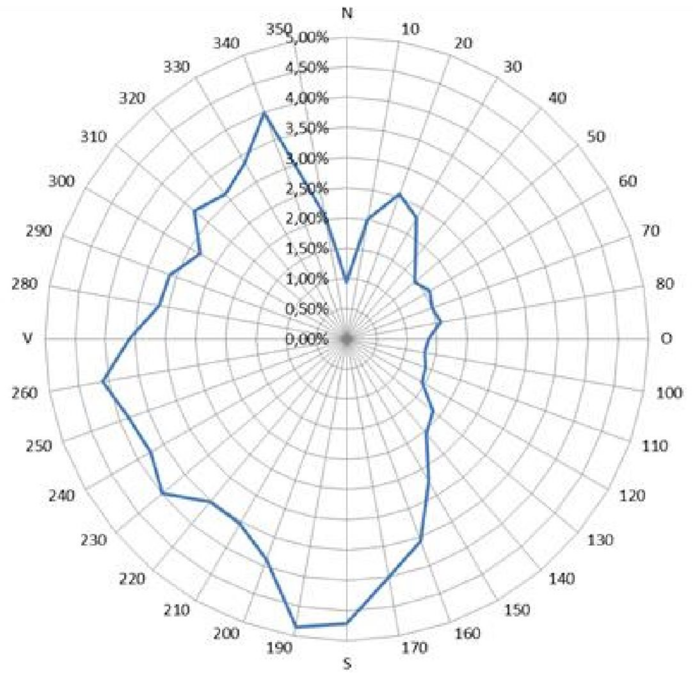

Figure 1-10. Wind direction and duration at the Simpevarp peninsula in 2010-2013.

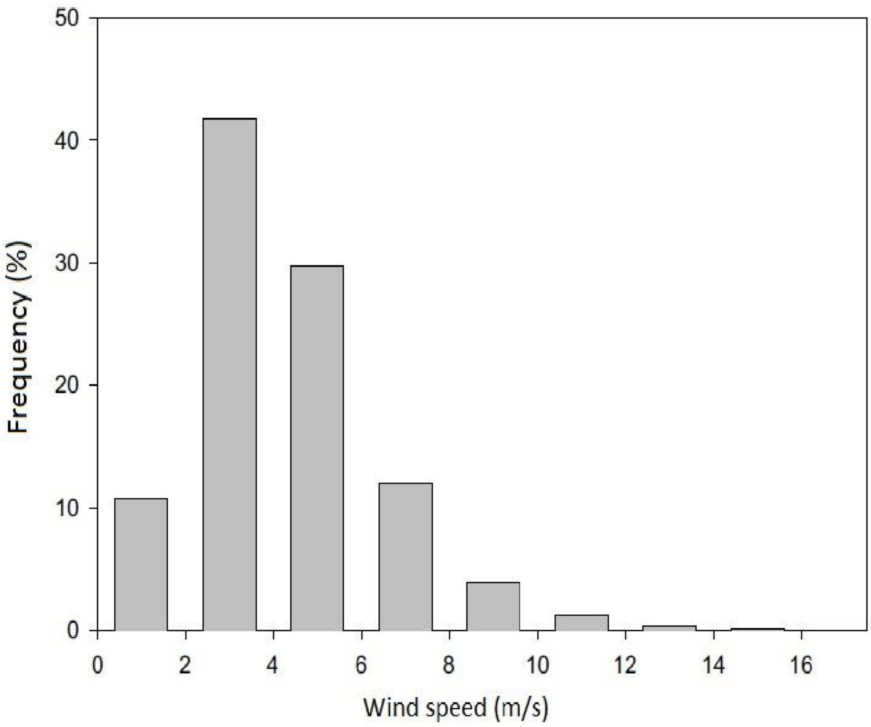

Figure 1-11. Wind speed distribution at the Simpevarp peninsula, at 25 metres in 1996 - 2000 [26].

The wind speed and direction has been measured [8] at the northern tip of the island Öland over a long period of time, see table 1-4 and figure 1-12.

Table 1-4. Wind speed at the northern tip of the island Öland [8]. Until 1979, the wind measurement was done at the height 35 metres and as from 1980 the wind measurement was done at the height 10 metres. As from 1996 the location of the measurement has been changed (still at the height 10 metres) and to an automatic weather station with increased accuracy.

Year	Max. velocity, m/s	Year	Max. velocity, m/s	Year	Max. velocity, m/s
1966	22	1980	23	1994	17
1967	24	1981	26	1995	19
1968	27	1982	21	1996	19.9
1969	28	1983	28	1997	21.1
1970	29	1984	22	1998	20.3
1971	33	1985	26	1999	19.5
1972	27	1986	22	2000	19.0
1973	29	1987	26	2001	21.7
1974	27	1988	23	2002	20.6
1975	30	1989	21	2003	24.3
1976	28	1990	20	2004	23.0
1977	27	1991	23	2005	19.5
1978	31	1992	22	2006	18.9
1979	25	1993	21		

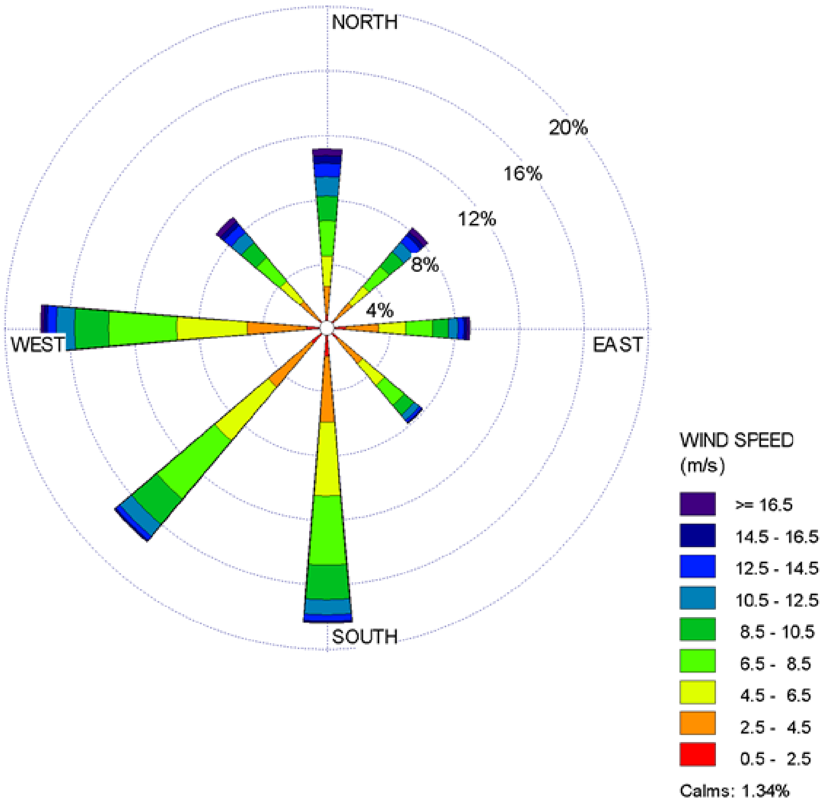

Figure 1-12. Wind directions and speed at the northern tip of Öland 1961 – 2005 [8].

Pasquill atmospheric stability class is a measurement of turbulence in air and is a parameter used in transport calculations of radioactivity in air. Values range from A (very unstable) to F (stable) and how turbulent the air is affects the spread of activity, figure 1-13. Most frequent for the Simpevarp location is class D.

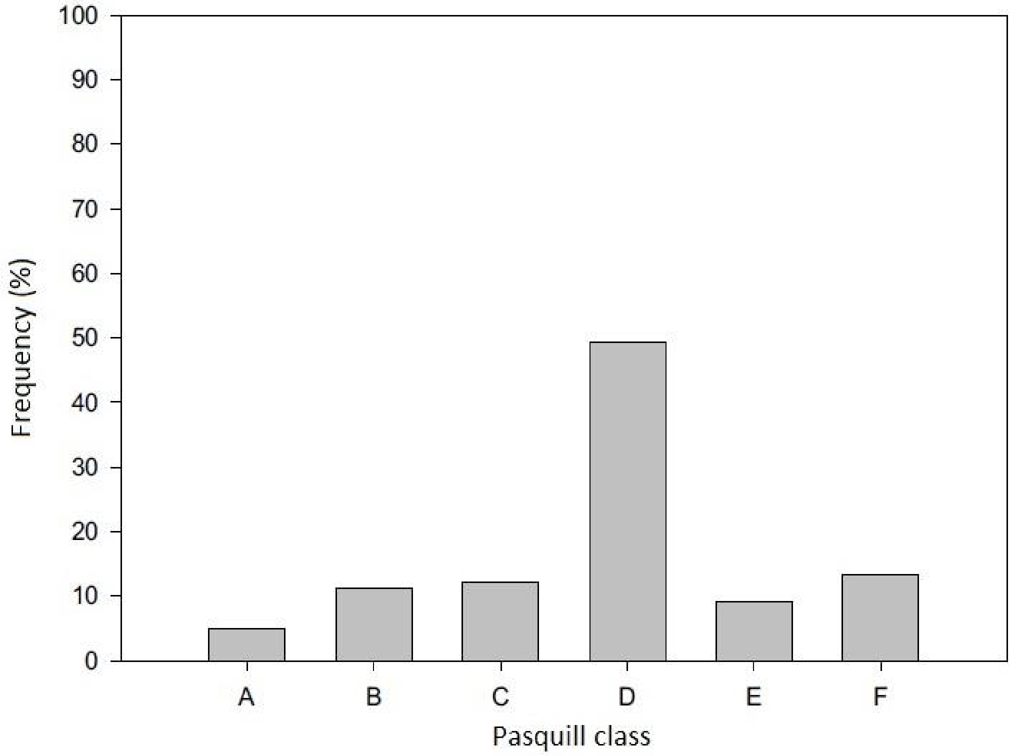

Figure 1-13. Relative distribution of calculated Pasquill class at Simpevarp, data 1996 to 2000 [26].

There is no specific calculation for the probability of local temperature inversion made from local measurements. There are calm conditions 1-2 % of the time and the topography with small height differences is not typical to give inversion.

Precipitation

The heaviest rainfall occurs during the summer and usually over a short period of time when thunder clouds appear. During the winter months, warm sea temperatures combined with a cold north-easterly wind can create heavy snowfalls which give a large amount of precipitation, see table 1-5 and figure 1-9. Annual precipitation is about 600 mm.

Table 1-5. Rainfall duration and intensity.

Frequency	Duration 10 minutes	Duration 60 minutes	Duration 24 hours
1/year	5 mm	10 mm	23 mm
1/100 years	17 mm	30 mm	75 mm

Extreme weather

Extreme weather (storm, tornadoes, ice storm, heavy rainfall) is rare in Sweden and especially on the Swedish east coast in relation to other parts of the world. Planned operations or transports during the decommissioning are not particularly sensitive to the weather conditions.

1.4 Natural Resources and Foodstuffs

The nearest protected area for drinking water resources is located in Fårbo, 11 kilometres from the site. Since 1983, drinking and process water for Oskarshamn nuclear power plant is taken from the Lake Götemaren through a pipeline to a water supply plant operated by Oskarshamn NPP. Lake Sörå is used as a reserve water supply for drinking and process water for the plant. Surface water in the close vicinity is used only on a small scale as drinking water for humans or to some extent for livestock in nearby residents.

Groundwater or surface water has no impact on water used in any neighbouring member states.

In the vicinity around Oskarshamn NPP, the density of the population is very low and there are few farms located nearby, main use of the land areas is forestry. The types of crops produced in 2015 and the numbers of different livestock in 2013, are shown in tables 1-6 and 1-7. The numbers of livestock included are those from Kalmar County (representing a wider area) and Oskarshamn. The use of arable land is dominated by production of fodder and grass for domestic animals.

Agricultural activities are low in the area around Oskarshamn NPP, no specific information exists of export of crops or livestock from this region to other member states. Since the region around Oskarshamn NPP does not produce any large quantity of foodstuffs, it is fair to assume that the significance of exports is negligible.

Table 1-6. Crops produced in Sweden as a total and in the county of Kalmar. No data exist for the smaller area, the municipal of Oskarshamn, around Oskarshamn NPP. The data is taken from the database DAWAS belonging to the Swedish Board of Agriculture for the year 2015.

Crop	Year	Sweden ton / year	Kalmar ton / year
Sugar beet	2015	1,200,000	4,500
Potatoes	2015	764,000	30,000
Rapeseed	2015	346,000	18,000
Cereal	2015	6,068,000	195,000
Leguminous plants	2015	170,000	2,000
Total		**8,548,000**	**249,500**
Percentage		100 %	2.9 %

Table 1-7. The amount of 4 different types of livestock in Sweden, in the county of Kalmar, and in the municipal of Oskarshamn. The data is taken from the database DAWAS belonging to the Swedish Board of Agriculture for the year 2013.

Livestock	Year	Sweden no.	Kalmar no.	Oskarshamn no.
Cattle	2013	1,496,526	150,790	4,136
Pigs	2013	1,398,875	74,092	1,821
Poultry	2013	16,540,365	1 914,829	455
Sheep	2013	576,769	38,050	1,802
Total		**20,012,635**	**2,177,761**	**8,214**
Percentage		100 %	10.8 %	0.04 %

2 The Installation

2.1 Brief Description and History of the Installations to be Dismantled

A compilation [9] has been performed collecting information with importance for the decommissioning. The information concerns for instance rebuilds, experiences of performed decontaminations or historical events with leakage of process or waste water that may have caused areas with contamination.

The construction of Oskarshamn 1, the first commercial nuclear reactor in Sweden, was initiated in 1965 and the unit was commissioned in February 1972. The second reactor Oskarshamn 2 was commissioned in January 1975.

The layout of the area that will be decommissioned, Oskarshamn 1 and 2 and the waste handling building is given in Figure 2-1. The dark blue area indicates process systems that have radioactive contamination and contamination of other equipment and building parts. Some buildings, apart from the waste handling building, are common for the two units, such as the containment venting filter building and the gas storage building.

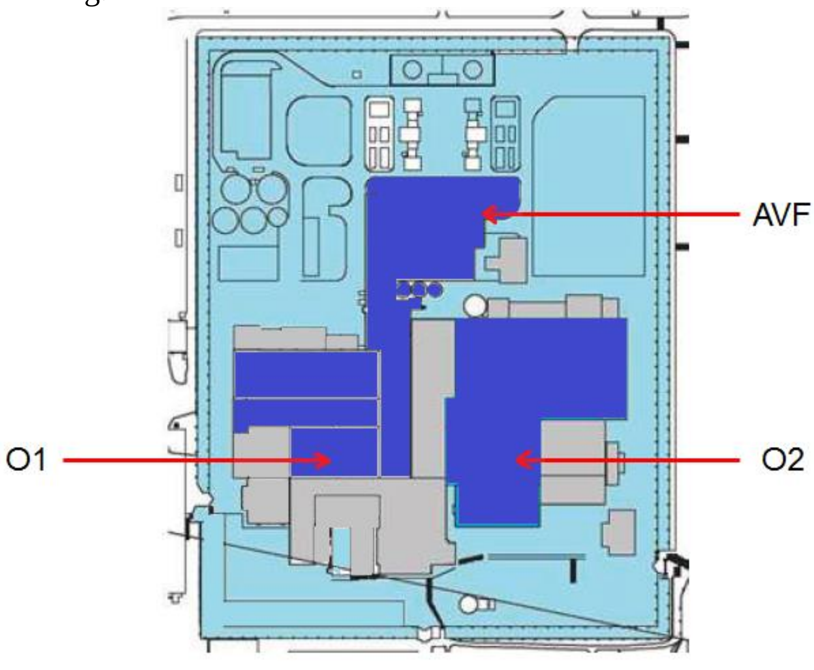

Figure 2-1. The dark blue areas indicate the buildings that contain radioactive materials, i.e. reactor buildings, turbine buildings, active workshops and the waste handling building. Other buildings belonging to Oskarshamn 1 and 2 are shown in the grey areas.

2.1.1 Description of Oskarshamn 1

Oskarshamn 1 is in operation and the plan is to permanently shut down the unit in July 2017. The spent fuel from Oskarshamn 1 will be transported to Clab (see appendix 3) by the end of 2018.

Reactor containment

The reactor containment is enclosed by the reactor building. The lower part of the reactor containment rests on the bedrock. The upper part of the reactor containment has a system of pre-stressed concrete beams and is cast together with the concrete wall surrounding the reactor tank. The interior of the containment vessel is separated into two different volumes: the dry well, where the reactor pressure vessel and all connecting piping are located, and the wet well, which is an annular chamber in the bottom of the containment vessel containing the condensation pool.

Reactor building

The reactor building comprises the reactor containment, process systems close to the reactor, spent fuel storage pools, and the handling pool. The reactor building is situated directly on the bedrock. The upper level is the reactor hall, were the spent fuel storage pools, handling pool, and the space for storing the reactor vessel head and dome during the outages is located. Most levels in the building can be reached with the overhead travelling crane for handling of heavy components, such as the internals and the fuel casks. The walls and the different levels were cast in situ. The building is insulated with mineral wool clad with corrugated metal sheets. The roof is mainly a steel construction.

Turbine and the intermediate building

The turbine building consists mainly of two different spaces, the primary turbine containment and the turbine hall. The turbine containment building contains the turbine, the generator, the condenser, and the steam culvert that leads from the reactor through the intermediate building to the high pressure turbine. The turbine hall contains the bus bar from the generator, preheaters, the auxiliary systems for the turbine and generator, and the lifting and handling equipment for maintenance. The primary turbine containment and the turbine hall are separated with concrete walls and concrete upper heads above the primary turbine containment.

The intermediate building consists of two parts, the lower and upper parts. The lower part contains the condensate and feed water pumps, preheaters, condensate filtering system, and auxiliary systems for the turbine. The upper part contains the ventilation system for the unit, the system for filtering radioactive gases and steam, and feed water lines. Walls and roof are constructed in the same way as for the turbine building.

Electrical building

The electrical building contains diesel generators, switchgear, control room, relay room, and ventilation equipment. The electrical building is constructed on a reinforced concrete floor with walls of lightweight concrete.

Sea water screening plant

The sea water screening plant contains equipment for filtration of cooling water from debris to supply the cooling systems for the plant with clean cooling water.

The sea water screening plant contains strainers for sea water, main cooling water pumps, cooling water pumps and heat exchangers for the operational systems. There is a small risk for contamination inside the heat exchangers for the secondary cooling systems

The walls are made of lightweight concrete and cast concrete against the underlying bedrock.

Office building

The laboratory for chemistry and radiochemistry is situated in part of the office building in a controlled area. It is principally the ventilation and drain systems in the laboratory that contain activity.

Active workshop

The active workshop serves as the workshop for mechanical and electrical components. The whole workshop was cast in situ with concrete, except for the roof which is a prefabricated concrete roof. The building can contain contamination.

Main stack

The main stack is situated on the steam line culvert close to the north side of the reactor building. The top of the stack is 76 metres above sea level or 70 metres above ground. The stack is made of metal sheets with insulation of mineral wool covered with corrugated aluminium sheet.

All technical properties of Oskarhamn 1 are shown in the table 2-1 below.

Table 2-1. Technical data for Oskarshamn 1.

	Unit	**Value**
Main supplier		
Reactor		ASEA-ATOM
Turbine		Stal-Laval
Time		
Construction start		1965
Start of operation		1972
Design volumes		
Reactor building	m^3	63,000
Turbine building	m^3	71,000
Volumes		
Total Construction	m^3	440,000
Blasting	m^3	80,000
Die cast	m^3	75,000
Concrete	m^3	35,000
Reinforcement	ton	2,500
Other design data		
Total height rector building	m	62
Altitude above sea	m	46
Stack height above sea	m	76
Reactor plant		
Thermal power	MWth	1 375
Electric power, gross	MWe	492
Electric power, net	MWe	473
Reactor pressure	MPa	7
Reactor steam temperature	°C	286
Steam flow	kg/s	650

	Unit	Value
Reactor pressure vessel		
Inner height	m	17.6
External height	m	18.0
Inner diameter	m	5.0
External diameter	m	5.3
Wall thickness	mm	125
Weight with RPV head	ton	414
Control rods		
Absorption material		B_4C
Number		112
Main reactor cooling pumps		
Number		4
Maximum flow per pump	kg/s	2,000
Turbine plant		
Electric power	MWe	491
Fuel		
Number of fuel assemblies		448

2.1.2 Description of Oskarshamn 2

Oskarshamn 2 is no longer in power operation and all the spent fuel is located in the spent fuel pool or has been transported to Clab. The fresh fuel has been modified and will be used in Oskarshamn 3.

Reactor containment

The reactor containment is enclosed by the reactor building and functions as a separate building. The fuel and reactor pools are located in the upper part of the reactor building. In the bottom of the reactor pool (the upper head of the containment vessel) there is a removable containment dome, made of painted carbon steel. By removing the containment dome, the head of the rector pressure vessel can be unbolted and removed, and access to the interior of the reactor pressure vessel is gained through the reactor pool. The interior of the containment vessel is separated into two different volumes; the drywell, where the reactor pressure vessel and all connecting piping are located, and the wetwell, which is an annular chamber in the bottom of the containment vessel containing the condensation pool.

Reactor building

The reactor building rests on bedrock blasted approximately 20 metres below ground level. The top level consists of the reactor hall. The majority of the floor is accessible by the overhead travelling crane, required for handling of heavy components and equipment. The other levels contain process equipment and components. Around the reactor containment there is an area for equipment and system parts that need to be kept close to the reactor containment.

The other parts of the reactor building primarily consist of the reactor auxiliary systems, steam systems, feed water systems, service and laboratory facilities and areas for fresh fuel and access paths.

The reactor building is mainly composed of concrete with a steel roof for structural support.

Turbine building

The turbine building consists of two equally sized building parts. One part contains the turbine and condenser and the generator whilst the other part contains the preheating system, condensate water clean-up equipment, feed water system, condensate pumps, turbine building ventilation system, and the off-gas treatment delay system. The walls of the turbine building are made of reinforced concrete. The roof on the north part is made of corrugated sheet metal whilst the southern part has a roof made of concrete.

Power and control building

The power and control building is located next to the reactor building and the turbine building at Oskarshamn 1.

The power and control building has movable joints between the surrounding buildings, which allows for the independent movement of the buildings. The main framework of the building is made of reinforced, in situ cast concrete boxes. The walls that are not facing other buildings are insulated with lightweight concrete. The building is not contaminated by radioactivity.

Sea water screening plant

The sea water screening plant contains equipment for filtration of cooling water from debris to supply the cooling systems for the plant with clean cooling water.

The building consists of two equally long parallel building sections. One section contains the main cooling pumps and the equipment for filtration. The building also contains pumps for the shutdown cooling water system and the normal operation cooling water system. The other section contains pumps and heat exchangers belonging to the secondary cooling system. Heat exchangers for the cooling systems may contain activity.

The main framework of the building consists of reinforced, in situ cast concrete. The roof main framework is for the most part composed of corrugated steel plates supported by chief beams of steel.

Auxiliary power building

The auxiliary building contains two diesel generators and their auxiliary systems. The building framework consists of reinforced, in situ cast concrete plates. The plates are locally reinforced with beams and columns. Below the building are drainage pipes which lead to the sea water screening plant. The building is not radioactively contaminated.

Active workshop

The active workshop serves as the workshop for mechanical and electrical components, as well as a storage and office space. Both the reactor building and the auxiliary power building can be accessed from the active workshop. The building ground plate is manufactured out of in situ cast concrete plates reinforced in the corners and below the building structure support. The main framework of the building is manufactured in lightweight concrete and supporting beams. The building may contain contamination.

Filtered pressure relief system building

The building contains safety features for severe accidents and is connected to both Oskarshamn 1 and 2. The building contains filtration equipment as well as a service building on one level of the building. Mounted on the building is a stack with a highest point of 27.4 metres above ground level. The concrete cylinder holds a tank space, filters, pipes and tap outlet for chemical analysis. The service building contains an area for valves and three power rooms. The building is detached from the other buildings. The system has never been used for filtration of radioactive gases, and the building and equipment are thus not radioactively contaminated.

Gas storage building

The building contains gas tanks for the distribution of carbon dioxide, nitrogen gas and hydrogen gas. The building frame consists of reinforced in situ cast concrete plates. The plates are locally reinforced with beams and columns. The outer walls are clad by corrugated steel sheet. The building does not connect to any other buildings. The building is not radioactively contaminated.

Transformer building

The transformer system consists of four buildings, one for each transformer. The building has a joint wall shared with the turbine building. The building ground plate is manufactured out of reinforced in situ cast concrete plates. The building is not radioactively contaminated.

North and south electrical buildings

These are two new buildings that were erected in 2013 in order to fulfil new reactor safety requirements. The buildings contain mainly electrical equipment, and they do not hold any components that are contaminated. The buildings are made of reinforced concrete with the outer walls clad with corrugated metal sheets. The buildings are not radioactively contaminated.

Main stack

The main stack is connected to the northern part of the reactor building and is made of concrete. The top of the stack is 110 metres above ground. The stack is radioactively contaminated on the inner surfaces.

All technical properties of Oskarshamn 2 are presented below in table 2-2.

Table 2-2. Technical data for Oskarshamn 2.

	Unit	Value
Main supplier		
Reactor		ASEA-ATOM
Turbine		Stal-Laval /Brown Boveri
Time		
Construction start		1969
Start of operation		1974
Design volumes		
Reactor building	m^3	106,000
Turbine building	m^3	150,000
Volumes		
Total Construction	m^3	320,000
Blasting	m^3	150,000
Die cast	m^3	180,000
Concrete	m^3	59,000
Reinforcement	ton	5,350
Other Design data		
Total height reactor building	m	70
Altitude above sea	m	49
Stack height above sea	m	116
Reactor plant		
Thermal power	MWth	1,800
Electric power, gross	MWe	661
Electric power, net	MWe	638
Reactor pressure	MPa	7
Reactor steam temperature	°C	286
Steam flow	kg/s	910
Reactor pressure vessel		
Inner height	m	20.0
External height	m	20.3
Inner diameter	m	5.2
External diameter	m	5.5
Wall thickness	mm	134
Weight with RPV head	ton	530
Control rods		
Absorption material		B_4C
Number		109
Main reactor cooling pumps		
Number		4
Maximum flow per pump	kg/s	2,550
Turbine plant		
Electric power	MWe	620
Fuel		

	Unit	Value
Number of fuel assemblies		444

2.1.3 Description of the waste handling building

Oskarshamn 1 and 2 have a common waste handling building, located adjacent to Oskarshamn 1. The waste handling building consists of waste water systems, waste handling plant and waste storage facility. The building is composed of in situ cast concrete and elements of concrete. The building has three water sumps. Two are situated inside the building and receive drainage from the process systems and floor drainage. The third sump is a ground water sump situated outside the building.

Liquid waste handling system

Radioactive liquid waste from the controlled areas is received and processed by the system for processing liquid radioactive waste in such a manner that the water can either be reused in the power plant or discharged into the cooling water channel. The system consists of an extensive system of piping with filters, ion exchangers and holding tanks, where system drainage, floor drainage and sludge waste from filters and ion exchangers are processed. Figure 2-3 shows the principal outline of the waste system.

Solidification of waste

The system for solidification of waste in concrete casks is located in the waste handling building. The system is used to condition used filters and ion exchange resins in a cement-matrix in concrete moulds. The system is also used to cast lids on the moulds with the conditioned waste. Ion exchange resins from the condensate clean-up system is filled in concrete tanks, and ion resin from the cooling and cleaning system for the fuel pool and from reactor water clean-up system containing more activity are moulded in concrete casks.

The waste handling system will be used as long as it is needed during decommissioning, in a corresponding manner as during power operation. More information about the waste handling system can be found in sections 2.3 and 2.4 of this report.

2.2 Ventilation Systems and the Treatment of Gaseous and Airborne Wastes

Oskarshamn 1 and 2 have separated ventilation systems, with similar design. The strategic concept for the ventilation is that the air flow is directed towards areas with higher risks of airborne activity. The ventilation system for the contaminated areas consists of different and separated subsystems that evacuate air from the reactor building, turbine building, waste building, inner controlled zone, and active workshop. All evacuated air is directed towards the main stacks to be measured and recorded during discharge to the surroundings, see figure 2-2 below.

During the decommissioning the requirements regarding filtration of exhaust ventilation from controlled areas will be regulated by license conditions issued by SSM. In the reactor building there is a possibility to connect the ventilation flow through a system of carbon filters, if necessary. The filter system consists of absolute filter/activated carbon/absolute filter. Delay systems and the filter system are designed to handle e.g. the venting from the condenser (off gases) during power operation, and the venting of the drainage systems that contain water from the process.

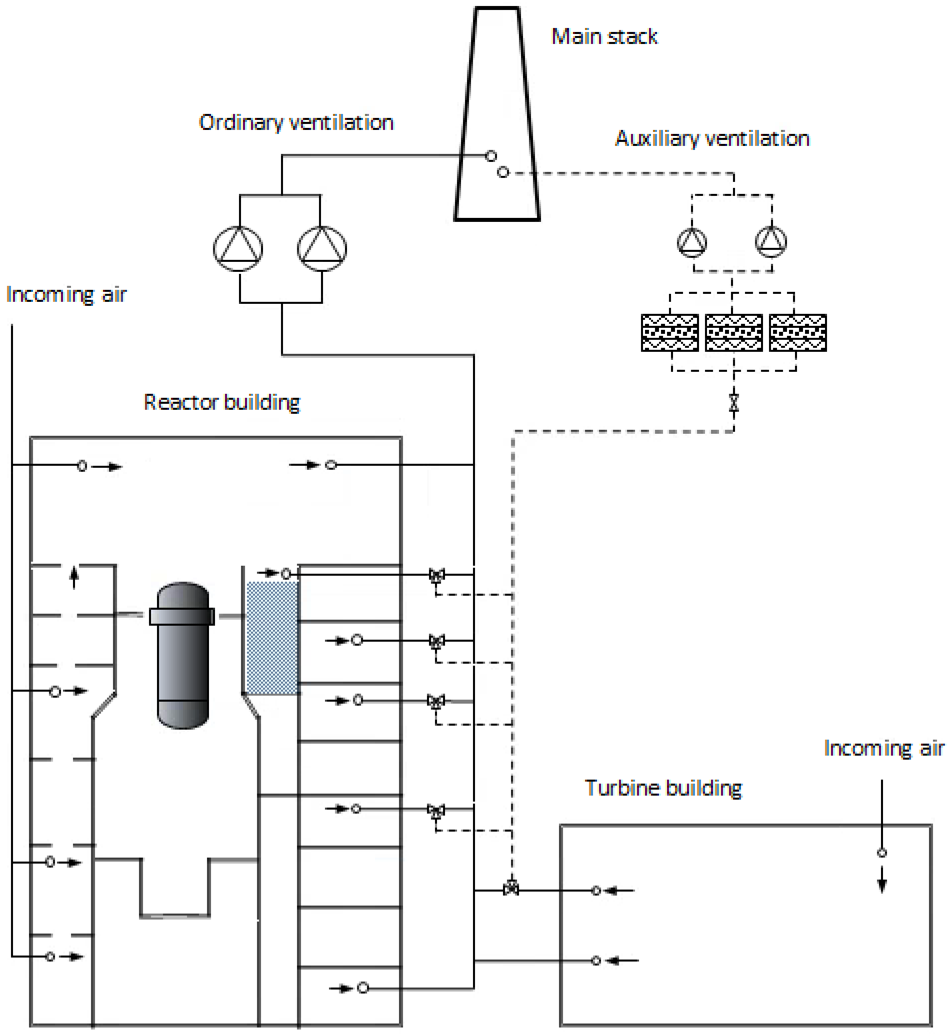

Figure 2-2. System for radioactive airborne effluents.

During the care and maintenance period, the ventilation of the areas with radioactive and contaminated material will continue to be in operation in the same manner as during normal power operation.

At some point during dismantling, the existing ventilation systems will be replaced by temporary solutions in order to meet the requirements on monitoring of discharges. Additional ventilation with filtration may be required depending on the risks identified during the planning process to have an acceptable working environment during the dismantling process.

2.3 Liquid Waste Treatment

Within the controlled area at Oskarshamn 1 and 2, all the water that is disposed off is led to the waste handling facility. Purification technology is focused on radioactivity and involves filtering supplemented by ion exchange. The aim after shutdown will be to purify the water in order to reduce the discharge of radioactivity to water.

In order to render the treatment of waste water easier, the choice of handling method is made with respect to the origin. Handling of liquid radioactive waste is divided into seven subsystems/lines as follows, see also figure 2-3.

Line 1
The system receives water from the process systems in the plant. The water is cleaned and filtered by ion exchange and carried into the storage tanks before being reused in the process. Water can also be directed to line 6 for discharge to the sea.

Lines 2 and 3
The systems receive and purify floor drains and decontamination water from Oskarshamn 1, Oskarshamn 2, the waste handling building, CSV and have the possibility to receive water from Oskarshamn 3. When the water is sufficiently clean it is pumped to line 6.

Line 4
The system is divided into three new subsystems which handle spent ion exchange resins and filter aid. In the plant, powder and granular ion exchange resins are used for the treatment of process water, as well as for the purification of other water in the waste facility. The granular and powdered resin with high activity content is pumped over to the system for the treatment of solid waste for solidification with cement in moulds. After interim storage, the moulds are transported to Forsmark for final disposal at the SFR (repository for radioactive operational waste, see appendix 3). The powdered resin from the condensate clean-up system has lower activity content. The waste in the concrete tanks is dewatered before they are sealed and transported to SFR in Forsmark after interim storage.

Line 5
Not in use.

Line 6
The system consists of a number of tanks that receive water from subsystems 1-4 and 7. The tanks have mixers for sampling that are carried out in a representative manner. After passing the sampling, water is pumped to the discharge channel for Oskarshamn 1 or Oskarshamn 2 to be discharged into Hamnefjärden and the sea. Sampling for activity monitoring is described in section 4.4.

Line 7
The subsystem consists of holding tanks that receive water from the spent fuel storage pools, condensate pools and flask lifting shafts. The system has the possibility to store and purify water for reuse in the pools. Purified water can also be directed to subsystem 6 for discharge to the sea.

Moulding
The system handles the medium active ion exchange resins and other solid waste and sludge. The waste is mixed with cement directly in the final container for waste moulds. The containers are sent to BFA, in which the nuclide-specific measurement and registration in the database occurs. After a period of storage in BFA, the containers are transported to SFR in Forsmark for final disposal.

Sludge and sediments from the sump pit in the controlled area within the facilities are generally collected in the waste system filters for floor drain in line 3. These filters are back flushed to a concrete tank. When cleaning the sump pits, the sludge and sediments are collected in containers. The container is transported to the waste facility where the contents are emptied into a concrete tank.

The capacity of the tanks in the different lines is presented in table 2-3.

Table 2-3. Capacity for the tanks used for the treatment of liquid waste.

Line	**Tank capacity (m^3)**
Line 1	960
Lines 2 and 3	232
Line 4	249
Line 6	810
Line 7	2280

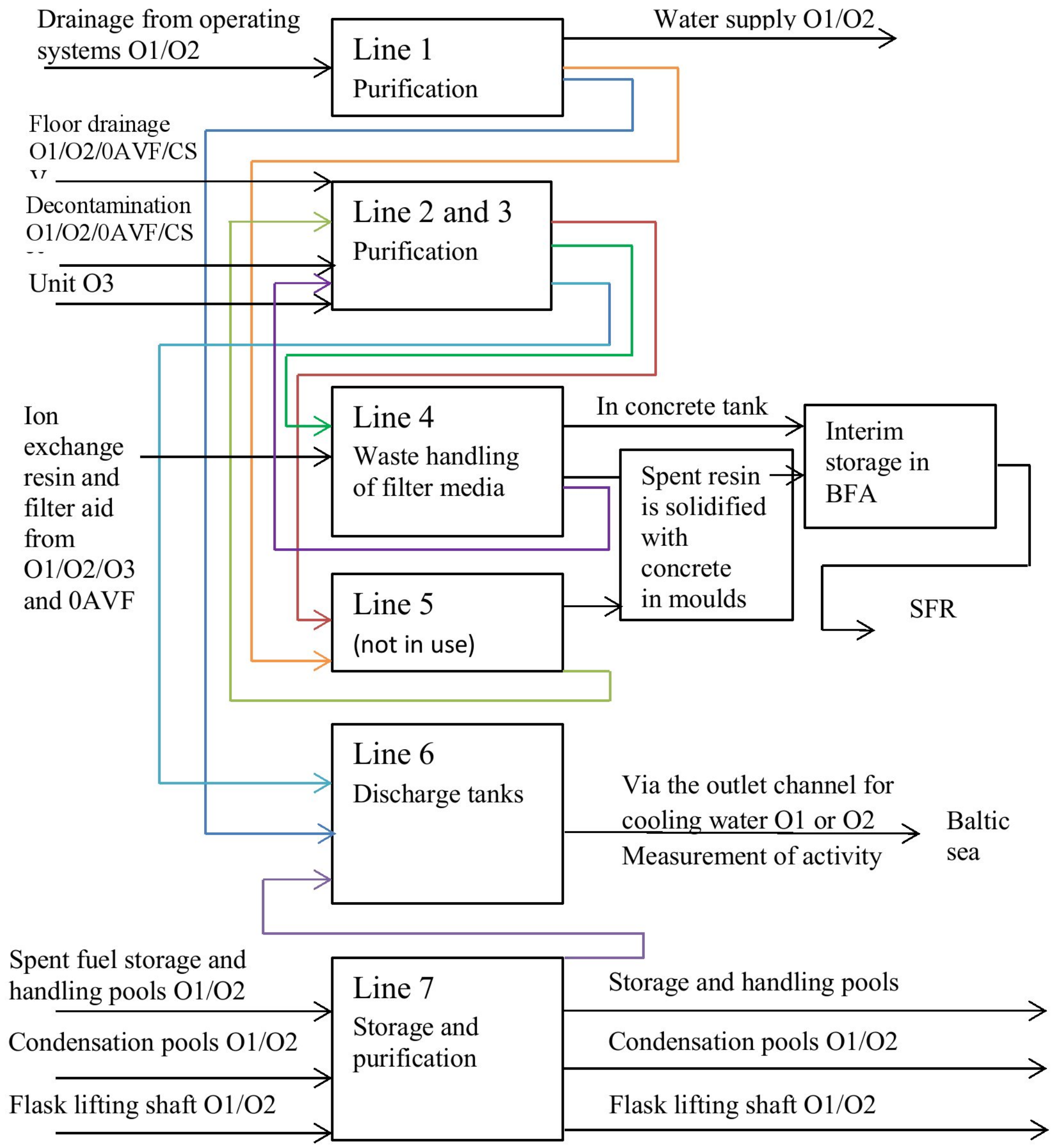

Figure 2-3. System for treatment of liquid waste at Oskarshamn 1 and 2.

2.4 Solid Waste Treatments

During the decommissioning of a nuclear power plant, there are large amounts of waste that need to be managed. However, only about 5-10 % is regarded radioactive waste, the remaining 90-95 % can be treated as conventional waste. All materials and structures are classified according to risk of contamination into following categories:

- Extremely low risk of contamination
- Low risk of contamination
- Risk of contamination
- Contamination above limits for free-release (i.e. radioactive waste)

Material and structures classified higher than extremely low risk (from low risk), should be handled as radioactive, or potentially radioactive (for additional information, see section 5.1.3).

Waste management in the context of decommissioning is a logistic commercial challenge, where capacity problems or stop in the waste management processes can have a high impact on the progress of the decommissioning project. For this reason, OKG has developed an overall waste strategy for the management of radioactive materials and wastes arising from the decommissioning of Oskarshamn 1 and 2 and the waste handling building 0AVF. The waste strategy is intended to cover all materials to be removed during the decommissioning (see figure 2-4 and appendix 3). The strategy clarifies the handling procedures for all waste categories and evaluates the different management and treatment concepts from a technical, environmental and economic perspective. The strategy for the management of radioactive solid materials and waste forms a basis for all other strategies, i.e. waste led decommissioning (for additional information, see section 5.1.2). Radioactive waste management plan is also a part of the decommissioning SAR to be approved by SSM.

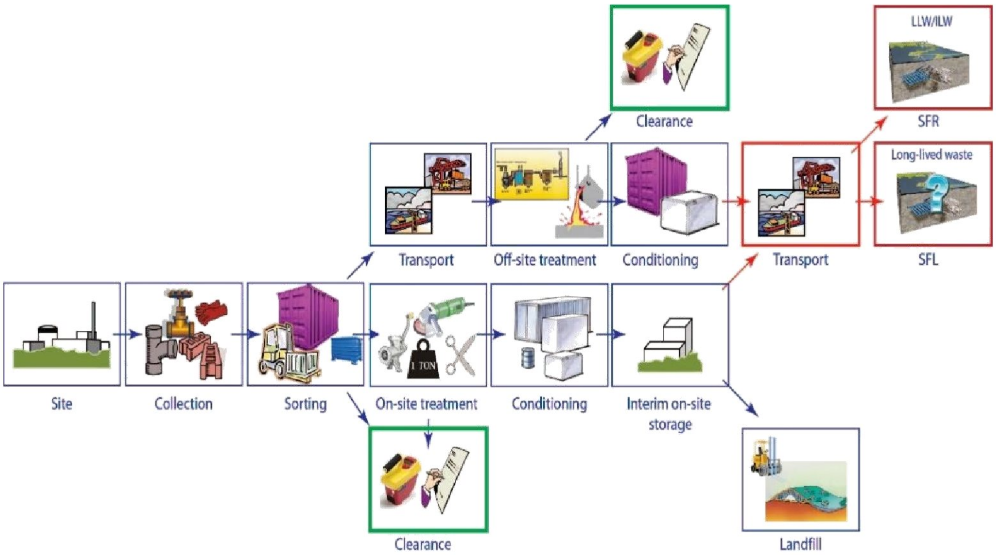

Figure 2-4. Waste management steps and waste route alternatives of radioactive solid waste during decommissioning. (Picture: Vattenfall Teknik)

2.4.1 Treatment

There are different treatment options for radioactive solid waste and below is given a short description of the methods that OKG considers using during the demolition and dismantling.

2.4.1.1 Waste treatments and decontamination methods

Chemical decontamination

It is advantageous to implement a chemical decontamination to reduce contamination levels of components and material in the nuclear power plant. The standard procedure is to perform chemical decontamination of heat exchangers, pumps, pipes and valves. Chemical decontamination can also be performed to reduce the dose rate, to reclassify the waste from intermediate to low level category and as an alternative method to reach levels that allow clearance.

Dismantling and mechanical reduction

An important part of waste treatment is the dismantling and mechanical processing of material. The treatment is used to optimize the size of the component or to reduce the activity of contaminated, or potentially contaminated, surfaces. Several different types of methods are used for mechanical segmentation, like sawing and shearing. Experience shows that the best is a combination of mechanical and thermal methods, such as using blowtorches or a plasma torch.

Melting

Melting is a method used to obtain homogeneous distribution of activity in an object with nuclides that cannot be separated as slag or waste gas. The radioactivity will be one with the metal structure, which is a benefit in those cases where clearance of the metal cannot take place, but must be deposited as radioactive waste in a landfill or a geological disposal. Another reason behind using melting is the volume reduction; to optimize the volume to the geological disposal. Materials that can be treated by melting are steel, aluminium, copper, brass and lead. Multiple companies worldwide can offer these services, including Cyclife Sweden AB at the Studsvik site in Nyköping. Exporting radioactive material, classified as nuclear waste according to Swedish legislation, for treatment and disposal is prohibited since the implementation of Council directive 2011/70/Euratom.

Hot water washing machine

A large amount of material from the decommissioning of a nuclear power plant is only lightly contaminated, which can be decontaminated with water based washing solutions. A hot water washing machine used for decontaminating material surfaces gives a good effect at a low cost. The water and filters will be treated and handled in the waste handling building for liquid waste (0AVF). For additional information of the waste handling system of liquid waste, see section 2.3.

High pressure cleaner

High pressure cleaning of contaminated items is an efficient waste treatment method. Activities should be conducted in a rinsing cabinet to avoid the spread of contamination.

Vacuuming, wiping and manual processing

Decontamination of waste items by vacuuming, wiping and manual processing is a proven method in order to avoid spreading of loose radioactive contamination and to remove local accumulations of activity.

Compaction

A large amount of the radioactive solid waste is bulky. By compaction performed prior to disposal, the volume of organic waste and other material with low density can be significantly decreased in a compactor. Compaction can also be valid for use on metal materials to obtain an optimized volume and a good use of the container volume.

Combustion of organic material

Incineration or combustion of radioactive waste is a proven waste treatment method used for several decades. The advantages of incineration are the volume reduction and that organic substances are destroyed. Traditional combustible wastes are for example rags, clothing, wood and paper.

Decontamination of concrete and buildings

Surfaces in an NPP could be contaminated to such an extent that they need to be decontaminated to meet clearance requirements. Regarding surfaces for which decontamination is required in order to reach clearance levels, there are several different techniques to apply, ranging from simple clean-up with dry or wet methods to removing the contaminated surface with some mechanical or thermal method.

Water blasting or hydro demolition are good methods to use when fire and explosion hazards prevail or when dust from traditional blasting could cause problems. The advantage of this method is that the risk of airborne activity is reduced, but the disadvantage is that the water must be treated and disposed of. The advantage of dry methods in comparison to wet methods is that the volume of waste will be reduced because there is no need to treat the active fluid waste. Traditional methods like planing/scabbling/shaving but also methods like removable coverings, nitro-jetting, laser and plasma may be considered in the future decontamination of buildings and concrete.

2.4.1.2 Waste management and treatment at the OKG site

Collecting/Sorting

Radioactive wastes and materials are categorised based on their activity and dose rate. Hazardous waste is also categorised since it is generally forbidden to be disposed off in either landfill or geological disposal, SFR. If the only way to dispose off the hazardous radioactive waste is in SFR, it can be permitted after approval by SKB, but clearance is the preferred end-state when possible.

Collecting and sorting during decommissioning will be made in similar way as during operation. A brief overview of sorting and collecting references is described in table 2-4. There are more specific requirements for each waste category than described in the table (for additional information, see section 5).

During decommissioning a slightly more differentiated categorization for material and structures categorized as contaminated above limits for free-release is considered necessary, especially for VLLW and LLW where the bulk of radioactive waste is considered to be. An initial differentiated categorization is described in 5.1.3.

Table 2-4. Sorting and collecting references of radioactive solid waste.

Waste category	**Activity/Dose rate**	**Planned End-state**
Cleared waste	< 40 kBq/m^2	Clearance
Metallic waste	< 0.1 mSv/h (Metal)	External treatment, melting for clearance or volume reduction
VLLW	< 0.3 mSv/h Sorting by compactable and non-compactable in different collection containers.	Landfill *Note: Internal requirements by sorting/collecting VLLW is 0,3 mSv/h.* *The license states 0,5 mSv/h.*
LLW	< 2 mSv/h Sorting by compactable and non-compactable in different collection containers.	Geological disposal SFR
ILW	> 2 mSv/h	Geological disposal SFR/SFL

On site treatment

VLLW/LLW

After collecting and sorting compactable low level waste (LLW) the material and waste will be compacted into 1 m^3 waste bales and placed in an ISO-container. Sorted metal will be placed in a container. All containers that contain LLW will be stored in the interim storage on site, close to the dismantling and demolition area, until disposal in a landfill or in SFR. The planned area will be located next to the existing interim storage of LLW (LLA).

ILW

A large amount of the intermediate-level waste (for example ion exchange resin, metal, plastic, rags) will be collected and categorised, to be conditioned into a mould in the waste handling building 0AVF. After the waste handling process, the moulds will placed in BFA (the bedrock depository for active waste) until transportation and disposal in SFR. The waste has been handled in a similar way since 1972.

Long-lived radioactive waste

According to the present plan, the packaging of long-lived low and intermediate level radioactive waste such as internal parts will be placed in concrete or steel tanks. Since the waste acceptance criteria of the geological repository for long-lived radioactive waste (SFL) have not yet been decided by SKB, the requirement stipulates that the segmented internal parts shall be handled in such a manner that re-conditioning is feasible, if necessary, at the time final disposal is available.

Material and waste, partly secondary waste after segmentation of internal parts, will be placed in an individual steel box. This box can be handled in two alternative ways:

Option 1: The box with the secondary waste is placed in a scrap cassette, which is transported to an external interim storage (Clab). This entails possible conditioning and disposal at SFL later on.

Option 2: The box with the secondary waste is placed in a steel tank and goes through the same handling process as the neutron activated internal parts of the reactor.

Packages

All radioactive components and material will be conditioned in approved packages according to the Swedish transportation requirements [10-11] and waste acceptance criteria stipulated for each end-state alternative.

Further information on waste characterization, waste volume and the alternative end-states and interim storage capacity on site at OKG is given in section 5.

Storage

BFA is an underground storage facility for low and intermediate level radioactive waste in a rock cavern accessed within the controlled boundaries of OKG. BFA was built and licensed in 1980 and the storage facility has a total storage area of 5,000 m^2 and the capacity for storage is 13,500 m^3.The waste has no surface contamination since it is enclosed in concrete and steel moulds, steel boxes, concrete and steel tanks and the like. The facility is regularly inspected, tested and the rock drainage is collected. All aisles (rock tunnels) have waterproof floors of concrete with separate floor drains which are drained to a collecting tank.

The storage building for low level waste is located on the southern part of the location area and consists of four buildings; LLA1, LLA2, LLA3 and LLA4. LLA1 and LLA2 are used for storage of low level waste, partly for the subsequent handling in the handling facility for low level waste, and in part prior to the final disposal. LLA3 and LLA4 are larger and mostly used as interim storage of processed low level scrapped goods, which are stored in containers. LLA3 and LL4 also store larger components for which clearance will be performed and other low levelled waste to be placed in the final repository, SFR. These buildings are mainly constructed in concrete and the outer walls are covered in steel plates. The roof and its supporting framework are made of steel.

The individual storage capacity of the buildings are approximately:
LLA1: 450 m2/800m3
LLA2: 525 m2/1000m3
LLA3: 1200 m2/4600m3
LLA4: 600 m2/2300m3

2.5 Containment

Induced activity from the construction material is tied to the material during dismantling and demolition. The oxide coating that normally occurs on the inside of the system is protected until the process of dismantling is begun. Other materials, like ion exchangers and water, are processed in the treatment plant. Release to air goes by the ventilation system and is monitored. In some cases it is possibly to lead the air through carbon filters prior to release to the environment. Active components will be treated within the existing buildings such as the reactor building, the turbine building, the waste building, BFA or in temporary buildings designed to contain any risk of cross contamination outside the building. Dismantled components and building waste will be free released, after clearance, or sorted due to activity and then packed according to clearly defined routines.

For all nuclear power plants in Sweden there is an established system, the Swedish system, managed by SKB AB on behalf of the nuclear industry in order to ensure the safe handling of all nuclear waste and fuel, see figure 2-5 and appendix 3.

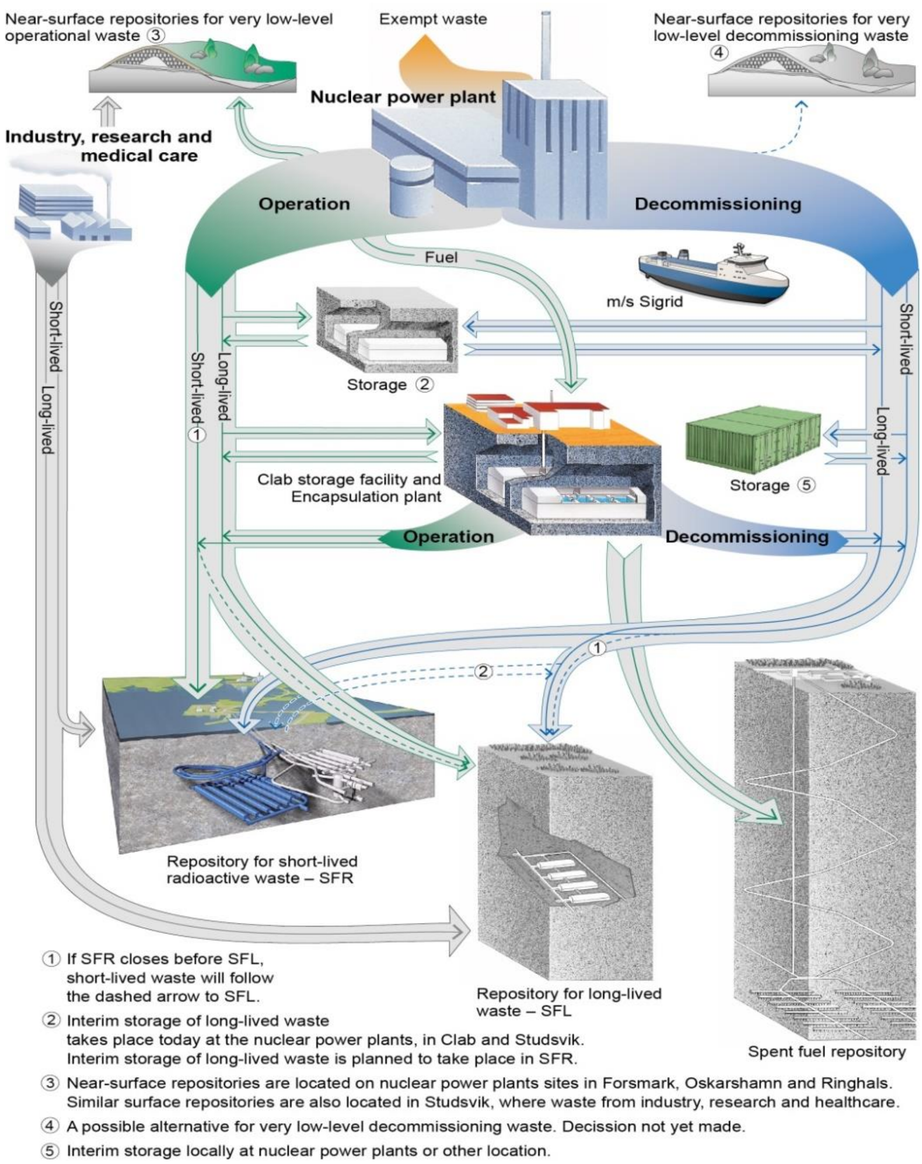

Figure 2-5. The Swedish system of the radioactive waste management arising from a nuclear power plant during both operating and decommissioning, including interim storage, alternative end-states and transportation routes with the Swedish Nuclear Fuel and Waste Management Company ship m/s Sigrid.

A description of the waste handling process from the time it is produced until it has been finally deposited into SFR and SFL is required, including interim storage criteria and transportation criteria [12]. These waste type descriptions meet the waste acceptance criteria (WAC) for the repository and are approved by the Swedish Radiation Safety Authority. OKG also has internal waste type descriptions of the radioactive solid waste planned for the landfill, to ensure safety during the entire waste handling process. For external treatment, the acceptance criteria of the treatment are established by the company performing the treatment, and the requirements have to be met by the nuclear power plant before the waste is treated. After treatment the waste is either returned to OKG for further treatment, or the supplier will package the residual radioactive waste in accordance with the associated waste type description.

In accordance with the above, one of the most important documents, ensuring well-planned and safe waste management is the waste handling plan. This plan should form part of the safety analysis report (SAR). Also the different waste type descriptions should be part of the SAR, both at OKG (as being the waste producer) and SFR. Before a new kind of waste is being produced, the waste type description should be handed in to SSM for review and approval.

3 Release from the Installation of Airborne Radioactive Effluents in Normal Conditions

3.1 Authorisation Procedure in Force

3.1.1 Legislation on nuclear activities

The Act on Nuclear Activities 1984:3, the Radiation Protection Act 1988:220 and Ordinance 2008:452 with instructions for the Swedish Radiation Safety Authority have been translated into English and can be found on the SSM website (www.ssm.se). These acts and ordinance, together with the Ordinance on nuclear activities 1984:14 and the Radiation Protection Ordinance 1988:293, stipulate the boundaries for all nuclear activities in Sweden. SSM has developed regulations (SSMFS) to give a more detailed framework for e.g. nuclear power plants. Some of the regulations are available in English.

SSM supervises that nuclear operations are conducted safely by issuing regulations as well as carrying out follow-ups and checks of activities related to nuclear safety. One aim is to ensure that personnel and environment are exposed to as little radiation as possible.

The most important regulations with respect to this report are:

– SSMFS 2008:1: The Swedish Radiation Safety Authority's Regulations and General Advice concerning Safety in Nuclear Facilities

– SSMFS 2008:23: The Swedish Radiation Safety Authority's Regulations on Protection of Human Health and the Environment in connection with Discharges of Radioactive Substances from certain Nuclear Facilities

– SSMFS 2008:51 The Swedish Radiation Safety Authority's regulations concerning basic provisions for the protection of workers and the general public in practices involving ionising radiation

– SSMFS 2011:2: The Swedish Radiation Safety Authority's regulations and general advice concerning clearance of materials, rooms, buildings and land in practices involving ionising radiation

Radioactive releases from nuclear facilities in operation are regulated in SSMFS 2008:23 (not verbatim):

- Discharges of radioactive substances must not cause more severe effects on human health and the environment outside the borders of Sweden than levels accepted within Sweden. (Section 3)

- Limitation of discharges of radioactive substances from nuclear facilities shall be based upon optimization of radiation protection while using the best available technique (BAT). (Section 4)

- The effective dose to any individual in the reference group by a yearly discharge of radioactive substances to water and air from all facilities situated within the same geographical area (i.e. from OKG and Clab) shall not exceed 0.1 mSv. The dose factors to be used for oral intake as well as intake by inhalation are given in Annex III of the Directive 96/29/Euratom. If the estimated dose is 0.01 mSv or higher per calendar year, realistic calculations shall be performed regarding the most affected area. (Section 5)

- Reference values and target values shall be determined for each nuclear reactor. (Section 6)

- Discharges of radioactive substances from nuclear facilities into air and water shall be checked by means of measurements. There are requirements regarding detection levels of the analyses. Nuclides to be reported are listed according to 2004/2/Euratom. (Section 12)

- Releases into air via the main stack shall be checked by means of continuous nuclide-specific measurements of volatile radioactive substances such as inert gases, nuclide-specific measurements of continuously collected samples of iodine and particle-bound radioactive substances, and measurements of carbon-14 and tritium. (Section 13)

- The function of the monitoring equipment and systems to limit discharges shall be checked regularly and whenever a malfunction is suspected. (Section 16)

- Environment checks shall be conducted in the vicinity of a nuclear facility according to a scheme determined by SSM. (Section 20)

– Monitoring of gamma radiation shall be performed continuously in the vicinity of nuclear power reactors. (Section 22)

– Reporting regulations are specified in Sections 24-28.

Radioactive releases from nuclear facilities that are being dismantled and decommissioned are not specifically regulated in any SSMFS at present. Some requirements for decommissioning are mentioned in SSMFS 2008:1 Chapter 9 (not verbatim):

– Before dismantling of the facility may be initiated, the decommissioning plan shall be supplemented and incorporated into the facility’s safety analysis report. The report is reviewed and approved by the Swedish Radiation Safety Authority. The Environmental Impact Assessment which is submitted to the Environmental Court in accordance with the Ordinance on Environmental Impact Assessments (1998:905) shall be attached to the revised safety analysis report. (Section 2)

On the Simpevarp Peninsula there will still be one nuclear reactor in operation (Oskarshamn 3) and the Clab facility for interim storage of spent nuclear fuel, which require environmental surveillance still after Oskarshamn 1 and 2 are fully decommissioned. The dose limits for the reference group specified in SSMFS 2008:23 are thus valid as well as the requirements to measure discharges to air and water.

SSM will issue conditions related to radioactive releases for facilities that are being dismantled and decommissioned. The conditions will include the handling of discharges and waste during dismantling and demolition. For discharges there will be conditions regarding mitigation and monitoring in the same way as in SSMFS 2008: 23.

In this report the requirements stipulated in SSMFS 2008:23 constitute the basis for further analyses.

3.1.2 Discharge limits and associated requirements for decommissioning

In Sweden there are no discharge limits in Bq for the time before the envisaged dismantling operations or the dismantling operations themselves. The limits are instead on ***the annual dose to the reference group*** living in the vicinity of the Simpevarp peninsula, which ***shall not exceed 0.1 mSv*** (SSMFS 2008:23 Section 5). The dose limit is on the total dose received, i.e. it is not specified how much can be received from discharges to air or water. The discharges are reported in Bq as well as in mSv. The focus for reducing the discharges is on Bq, since during power operation the dose is dominated by C-14 that cannot be easily reduced since it is proportional to the thermal power production.

For each reactor reference and target values shall be determined (SSMFS 2008:23 Section 6).

– The ***reference value*** for a nuclide, or a group of nuclides, is the normal optimized discharge level that is possible to reach during power operation, and can be considered as a measure of the ability of a nuclear reactor to limit the discharges.

– The ***target value*** for a nuclide, or a group of nuclides, is a measure of the level of ambition to lower the activity discharges in a short and long term perspective.

The reference and target values are sent to and approved by SSM every five years.

It is difficult to compare historical reference and target values due to changes in methods to calculate discharges starting in 2011 [13]. As from 2011, effects of detections limits are included in the calculation of the discharges in accordance with 2004/2/Euratom, but the effects are insignificant for nuclides that are detected on a regular basis. The nuclides that have been used have varied for the different periods. In tables 3-1 and 3-2 the reference and target values for 2011-2021 are given in Bq [14-16]. In addition, aerosols and noble gases as groups had reference and target values in 2011 as a part of OKG’s commitment to the environmental court.

Table 3-1. Reference values in Bq for 2011-2021, discharges to air.

Unit	Nuclide	2011	2016	2021
Oskarshamn 1	Co-60	2.3E+07	2.0E+07	2.0E+07
	I-131	3.1E+07	1.0E+07	-
	Noble gases	7.6E+13	-	-
	Xe-135	1.7E+13	8.0E+11	-
Oskarshamn 2	Co-60	5.0E+07	2.0E+07	2.0E+07
	I-131	3.4E+07	1.0E+07	-
	Noble gases	4.9E+13	-	-
	Xe-135	2.6E+13	2.0E+12	-

Table 3-2. Target values in Bq for 2011-2021, discharges to air.

Unit	Nuclide	2011	2016	2021
Oskarshamn 1	Aerosols	2.0E+08	-	-
	Co-60	2.0E+07	2.0E+07	2.0E+07
	I-131	1.4E+06	1.0E+07	-
	Noble gases	2.0E+11	-	-
	Xe-135	2.0E+11	8.0E+11	-
Oskarshamn 2	Aerosols	1.0E+08	-	-
	Co-60	2.0E+07	2.0E+07	2.0E+07
	I-131	9.1E+06	1.0E+07	-
	Noble gases	2.7E+12	-	-
	Xe-135	9.0E+11	1.0E+11	-

Every year in January the nuclear power plants report to SSM on their efforts and results to decrease the discharges to air and water. The annual report on discharges for the past year is submitted in March. The reference group in the annual report is divided into six different subgroups; infants 0-1 years, children 1-2, 2-7, 7-12, 12-17 years and adults for the dose factors that have been in use since 2002 (see section 3.4). Children 7-12 years receive the highest dose in the reference group during power operation.

For both Oskarshamn 1 and 2, the dose from aerosols has been dominated by Co-60. Noble gases and radioactive iodine have short half-lives and will thus decay and not be present during decommissioning. Once the fuel is removed from the nuclear reactor the possibility of having discharges of noble gases is non-existing. This is also the reason why only Co-60 is suggested to have reference and target values for the period 2017-2021. These values have not yet been approved by SSM.

3.1.3 Environmental impact assessment

The Environmental assessment procedure follows the required steps stipulated in the Swedish Environmental Code. In 1999, 16 different laws in the environmental area were incorporated into one Environmental Code. In order to provide a high level of protection of the environment and reduce the environmental impact, all environmentally hazardous activities and operations had to apply for a new license in accordance with the Environmental Code. The new license replaced all previous licenses in accordance with the old legislation

Early in the Environmental assessment process a public hearing is held involving the authorities, neighbours and other stakeholders. An environmental impact statement (EIS) must be submitted together with the application. The EIS describes the direct and indirect impact of the planned activity. The EIS includes a site description of the plant or activity as well as descriptions of the technology that will be used, considering the best available technique (BAT). Different alternatives for both these aspects are compulsory. The EIS also describes the impact on people, animals, plants, land, water, air, climate, landscape and the cultural environment. Furthermore, it describes the impact on the management of land, water and the physical environment in general, as well as on the management of materials, natural resources and energy.

The Swedish Environmental Protection Agency, Swedish EPA, the County Administrative Board (CAB), the local Environmental and Public Health Committee and the Swedish radiation protection agency are also consulted later in the licensing procedure and are given the opportunity to propose conditions.

In December 1999, OKG AB applied to the Land and Environmental Court for a license for an extension of the landfill for very low level radioactive waste. The license according to the Environmental Code was issued in December 2000 with several conditions ensuring the protection of the Environment and Human Health. In May 2004, OKG AB applied for a license for all other operations, including Oskarshamn 1, 2 and 3, waste handling of radioactive, hazardous and conventional waste, effluents to air and water and the like. This license was issued in August 2006 with a condition among others stipulating that measures should be taken to decrease the total release of radioactive discharges to air and water. A programme for this is currently in progress.

There are still a few older court rulings valid for water operations issued by the Water Court.

In order to prepare for the decommissioning of Oskarshamn 1, OKG applied for a license to change to post-operation phase in June 2015. The license was issued in June 2016. This license also covers the care and maintenance phase and partial dismantling of internal parts.

Later the same month, OKG submitted a similar application for Oskarshamn 2. The assessment procedure for this license is still ongoing and the license is expected to be issued in the middle of 2017.

The process for the application for dismantling and demolition for Oskarshamn 1 and 2 and the common waste handling building has recently started. The public hearing has been held and work is ongoing to prepare the application in accordance to comments from the stakeholders. The plan is to submit it to the regional Land and environment Court in Sweden in June 2017.

3.2 Technical Aspects

2004/2/Euratom [17] specifies the nuclides that must be reported from nuclear facilities concerning discharges to air and water. In addition, all nuclides present in the discharges that have a half-life longer than 40 hours are reported. Detection limits are reported, and for some so called key nuclides, in accordance with 2004/2/Euratom, the ability to detect these is specified.

During the care and maintenance phase, there are only trace amounts of fissile material in the facilities. There will be no production of fission products or neutron activation of corrosion products. OKG will apply for an exemption from the requirements to continuously measure noble gases and continuously collect and measure iodine. Other nuclear facilities under decommissioning in Sweden have been granted permissions from SSM to discontinue these measurements once the fissile material is removed.

Some discharges of C-14 and tritium will be detected even after the nuclear reactors have been shut down permanently. Experience from Oskarshamn 2 shows that C-14 continues to be released for a couple of months after the final shutdown. C-14 is also known to be released from the treatment of condensate clean-up ion exchange resins [18]. The level of tritium will be affected by the radioactive decay as well as the addition of fresh water. In Oskarshamn 2 tritium is still detected occasionally even three years after shutdown. Tritium is also released if the control rods are damaged. The control rods will be removed from the facilities in 2018 for Oskarshamn 1 and 2019 for Oskarshamn 2. As the activity concentration decreases in the fuel pools it will be more difficult to detect tritium in the main stack. Tritium has low dose factors and does not affect the dose to the reference group.

Focus in this report will be on Co-60, which is the most important nuclide in the aerosol discharges to air. In 2016 the nuclide composed 92 % and 100 % for Oskarshamn 1 and 2 respectively of the total dose from aerosol discharges.

Aerosols are collected using aerosol filters, presently in combination with iodine sampling with activated charcoal in a cartridge. Some other nuclides are also measured on the aerosol filters on a quarterly basis; alpha emitting nuclides (Pu-238/239, Am-241, and Cm-242/244) and strontium (Sr-89/90).

Discharges to air at normal conditions during dismantling and demolition will be affected by the following activities:

- Segmentation of reactor internals (Oskarshamn 1 in 2019, Oskarshamn 2 in 2018).
- Segmentation of the reactor vessels.
- Dismantling of contaminated systems and components.
- Treatment of spent ion exchange resins.
- Other dismantling operations.

Choice of segmentation technique and other technical aspects of dismantling and demolition will also affect the discharges. Values have been chosen to make sure the results are not underestimating the discharges.

For Oskarshamn 1 Ag-110m (half-life 250 days) is an important nuclide during power operation. In 2016, 92 % of the dose from discharges of aerosols came from Co-60 and 4 % from Ag-110m. The importance of Ag-110m will decrease as it decays significantly in the next couple of years. A major part of the silver is expected to be in the oxide film on the fuel elements, and will thus also be removed from the facility as the spent fuel is transported to Clab in 2018 (see appendix 3). This will be verified by sampling and analyses.

3.2.1 Origins of the radioactive effluents, their composition and physico-chemical forms

Radioactivity is formed during power operation in the following main processes:

- Neutron activation of materials close to the core.
- Neutron activation of corrosion products from surrounding systems that are transported to the core and the oxide film on the fuel cladding material.
- Fission products formed in the fuel element (contained as long as there are no fuel leakages) and from fission of fissile material on the outside of the fuel rods from previous fuel leakages (so called tramp uranium).
- Neutron activation of the cooling media.

Most of the radionuclides will decay and form stable elements soon after the final shutdown. During dismantling and demolition only long-lived nuclides will remain in the systems, in oxide films, in the concrete material if there have been leakages from e.g. the fuel pools, in ion exchange resins that have not been finally contained and in process waters that have not been drained.

Segmentation of reactor internals will be carried out under water for radiological protection reasons and to limit the amount of airborne radioactive aerosols. The waters will be cleaned by the fuel pool ion exchange resins, which also remove particles formed in the segmentation process. The reactor internals will not be chemically decontaminated before the segmentation, which means that both induced activity as well as activity in the oxide films will be present.

For the segmentation of the reactor vessel only induced activity is present since the vessel itself will be chemically decontaminated.

Co-60 will be the dominant nuclide when it comes to calculating dose to the reference group. All nuclides will be reported as usual to SSM according to SSMFS 2008:23 [2] and SSM2010/1157 [13].

The estimated discharges to air are based on calculations of total available activity of Co-60 for different components and systems and estimations of how much of this activity that will be discharged.

For Oskarshamn 1 the activity content for Co-60 is presented in table 3-4, [19]. The amounts are based on the activity content in 2034, four years after the reactor originally was to be shut down. The data has been recalculated to be valid at shutdown (1 July, 2017). No other nuclides are included since Co-60 will be the nuclide determining the total dose.

Table 3-4. Co-60 content in different locations/system/components at 1 July, 2017 in Oskarshamn 1.

Year	Location	Bq Co-60
2019	Reactor internals	1.30E+15
2019	Instrumentation	8.07E+14
2020-2021	Turbine building	6.21E+10
2021	Reactor vessel	1.47E+12
2021-2024	Primary system, containment, reactor building, reactor hall	1.71E+12
2022	Biological shield, concrete	1.19E+11
2022	Biological shield, armament	1.86E+11
2025-2026	Waste handling building	2.02E+10

The plan for dismantling and demolition of the different locations/systems/components is described in the introduction of this report.

In the calculations for annual discharges from Oskarshamn 1, some assumptions have been made:

- 50 % of the activity content from the primary system is released during 2021, the rest during 2022-2024.
- Half of the activity content from the turbine building is released in 2020 and 2021 respectively.
- The systems have been chemically decontaminated.
- The time of neutron activation for different components in the core area is taken care of in the original calculations [19].
- The waste handling building has been allocated to Oskarshamn 1 since it is connected to the main stack at Oskarshamn 1.

Corresponding data for Oskarshamn 2 are found in table 3-5. The data were originally presented in a report [20] and in this case data were given for 1 July, 2017 from the start. However, no decontamination was assumed.

Table 3-5. Co-60 content in different locations/systems/components at 1 July, 2017 in Oskarshamn 2.

Location	**Bq Co-60**
Biological shield, concrete	6.40E+10
Biological shield, armament	1.00E+11
Reactor vessel	1.00E+12
Reactor internals	7.50E+14
Instrumentation	4.50E+14
Primary system, containment, reactor building, reactor hall	2.30E+11
Turbine building	1.60E+11

The plan for dismantling and demolition for the different locations/systems/components is described in the introduction of this report.

In the calculations for annual discharges from Oskarshamn 2 some assumptions have been made:

– 50 % of the activity content from the primary system is released during 2020, the rest during 2021-2023.

– Half of the activity content from the turbine building is released in 2020 and 2021 respectively.

– Chemical decontamination is assumed to remove 90 % of Co-60 in the primary systems.

The assumptions are based on the strategy to remove the more contaminated systems in the beginning of the dismantling process, results from previous chemical decontaminations performed at OKG and the fact that decay affects the available activity content of the system.

The total nuclide inventory in Bq in Oskarshamn 2 is dominated by Fe-55 (68 %, half-life 2.6 years) followed by Ni-63 and Co-60 (15 % each) [20]. The dose factors for Fe-55 and Ni-63 (both weak beta emitters) are low, and the dose to the reference group will be dominated by Co-60. Approximately the same circumstances are true for Oskarshamn 1.

These data have been used with experience from previous segmentation of reactor internals. During the segmentation in 2012 in Oskarshamn 3 of the steam separator, core shroud head, core spray system, and the steam dryer [21] the total discharges to air of Co-60 were less than 1E+08 Bq. The total inventory in the components that were handled was 1E+15 Bq. Thus the factor 1E-07 has been used for calculating how much activity that can be discharged during dismantling and demolition of Oskarshamn 1 and 2. The factor is believed to overestimate the discharges. The segmentation technique used in 2012 (plasma cutting) will not be used this time. Cutting and shearing are believed to cause larger particles during the actual segmentation, which will be removed by the fuel pool filters.

The components that were segmented in 2012 in Oskarshamn 3 had been in operation for 23 years, which make them relevant for comparison. A long time of operation will give higher amounts of induced neutron activated nuclides in the reactor internals.

3.2.2 Discharges and doses during dismantling and demolition

Figure 3-1 presents the expected discharges for Co-60 for the complete dismantling and demolition phase. The discharges are also given in tables 3-6 and 3-7 for Oskarshamn 1 and 2 respectively, together with planned activities that will affect the discharges.

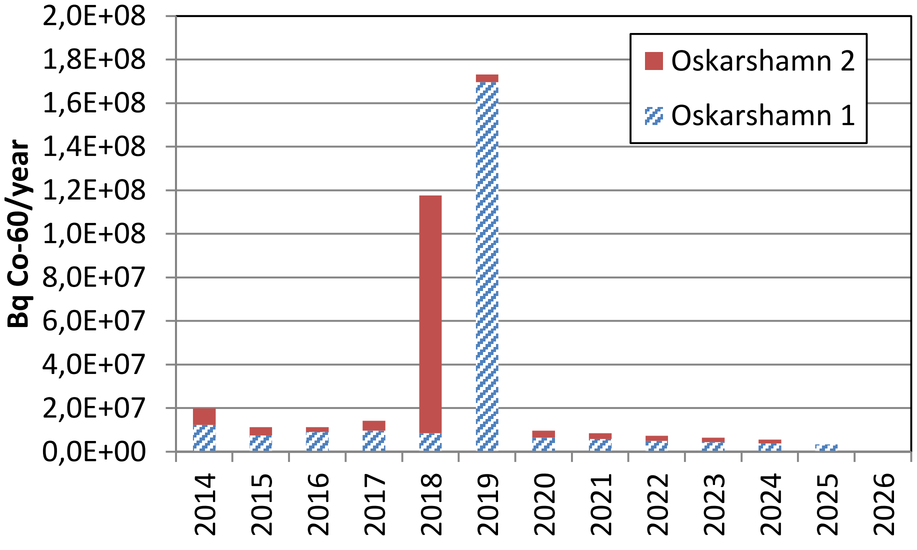

Figure 3-1. Discharges of Co-60 to air from Oskarshamn 1 and 2.

Table 3-6. Discharges of Co-60 in Bq to air from Oskarshamn 1.

Year	Oskarshamn 1 Co-60 (Bq)	Planned activities that affect the discharges
2017	9.7E+06	Power operation, shutdown, preparations
2018	8.5E+06	All spent fuel will be removed from the facility
2019	1.7E+08	Segmentation of reactor internals, instrumentation
2020	6.5E+06	Full scale decontamination, turbine, generator, less contaminated systems

2021	5.9E+06	Reactor vessel segmentation, containment, reactor hall
2022	5.0E+06	Biological shield, reactor building
2023	4.4E+06	Reactor building
2024	3.9E+06	Preparation for radiological clearance
2025	3.4E+06	Radiological clearance of the building
2026	0	

Table 3-7. Discharges of Co-60 in Bq to air from Oskarshamn 2.

Year	**Oskarshamn 2 Co-60 (Bq)**	**Planned activities that affect the discharges**
2017	4.5E+06	All spent fuel will be removed from the facility
2018	1.1E+08	Segmentation of reactor internals
2019	3.5E+06	Full scale decontamination Turbine, generators, less contaminated systems
2020	3.1E+06	Segmentation of reactor vessel, reactor hall, containment
2021	2.7E+06	Reactor hall, containment, reactor building, biological shield
2022	2.4E+06	Reactor building
2023	2.1E+06	Preparation for radiological clearance
2024	1.8E+06	Radiological clearance of the building
2025	0	

Segmentation of reactor internals will require one year per nuclear reactor. The work is planned to commence in 2018 for Oskarshamn 2 and continue in 2019 for Oskarshamn 1. The dismantling and demolition of different systems and buildings according to tables 3-6 and 3-7 are still subject for discussion. There are quite a few strategic decisions that must be resolved before the final planning is set. From a discharge perspective when calculating dose to the reference group and the surrounding environment in the perspective of this report, the conclusions will be the same.

Full scale chemical decontaminations are planned in 2019 for Oskarshamn 2 and in 2020 for Oskarshamn 1. The systems that will be decontaminated are mainly systems that during power operation transport process water to and from the reactor vessel, as well as drainage systems. Most of the radionuclides from the decontamination will be taken care of by the ion exchange resin in the reactor clean-up system. It has not yet been decided whether the reactor vessels also will be decontaminated. This depends on whether they will be segmented or transported intact to final storage. In this report it is assumed that the reactor vessels will be segmented after decontamination since this will give larger discharges to air. Most of the radionuclides from the segmentation will be taken care of by ion exchange resins in the fuel pool cleaning system.

The reactor halls are believed to be a major source of aerosol discharges due to the fact that the air goes straight to the main stack without filtering. As soon as the water is emptied out of the pools the aerosol discharges will be lower. Precautions to lower the discharges while emptying the pools are important, by cleaning and rinsing with water. This will take place in 2021 for Oskarshamn 2 and in 2022 for Oskarshamn 1.

The dismantling strategy is to start with the more contaminated systems. As soon as the more contaminated systems have been removed, the inventory that may cause discharges to air is significantly smaller. The discharges during the last years of dismantling and demolition will thus be lower.

The ventilation system will be in operation during the entire dismantling and demolition phase, in the original or temporary design. Sampling collection and analyses for aerosols will continue until the radiological clearance of the facility is done. Further information on the ventilation system is found in section 2.2.

Based on the discharges of Co-60 to air the dose to the reference group for infants 1-2 years, children 7-12 years and adults can be calculated. The results are shown in figure 3-2 and table App 2-1 (see Appendix 2). The doses are almost the same for infants 1-2 years and children 7-12 years.

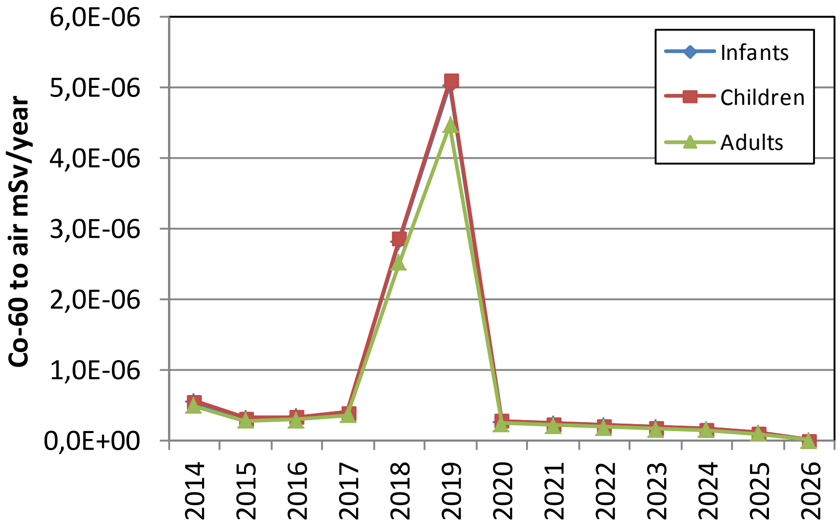

Figure 3-2. Estimated dose from Co-60 discharges to air from Oskarshamn 1 and 2 for infants 1-2 years, children 7-12 years and adults. Data can be found in Appendix 2.

During power operation, the dose is dominated by C-14. The annual dose received by children 7-12 years from OKG (all three units) in the last years of operation was approximately 2E-04 mSv/year, see figure 8-2.

The reference group will thus not receive higher dose from the dismantling and demolition of Oskarshamn 1 and 2 compared to what they receive during normal power operation.

For an infant of 1-2 years old to receive 10 µSv/year (0.01 mSv/year) from discharges of Co-60 to air from Oskarshamn 1 (which gives marginally higher dose than Oskarshamn 2, see table 3-9) 3.4E+11 Bq would have to be released. The calculated discharge of Co-60 is more than a factor 1,000 less.

3.2.3 Management of the effluents, methods and paths of release

The discharges to air are kept as low as possible by efficient cleaning in the fuel pool cleaning system. The air in the reactor hall is not filtered, and the ventilation systems in both Oskarshamn 1 and 2 have no filters that will be in operation during dismantling and demolition.

Experience from recent tests in Oskarshamn 3 shows that the main sources of aerosol discharge are the reactor hall and the fuel pools. To maintain low discharges it is important to use efficient filters in the fuel pool water cleaning systems. By this knowledge, it will be possible to monitor and prevent unnecessary discharges of aerosols from the reactor hall.

Other technical measures to limit discharges to air and water, for example local air filtration for work on specific contaminated components, will also be needed in order to meet the requirements in the conditions from SSM.

3.3 Monitoring of Discharges

3.3.1 Sampling, measurement and analysis of discharges

Oskarshamn 1 and 2 have a common laboratory in the controlled area, where chemical and radiochemical analyses are performed. In the stations there are also smaller laboratories for sampling and inline analyses (e.g. ion chromatography).

The laboratories in Oskarshamn 3 are organized in the same way. The laboratory for the environmental surveillance analyses is located in connection to the main laboratory in Oskarshamn 3.

Sampling of aerosols is done continuously and the filters are changed once a week in the system for activity surveillance in the main stack. The design of the system is the same in Oskarshamn 1 and 2, and follows the ANSI N13.1-1969 standard [22]. The system consists of a sampling device in the main stack with four nozzles to ensure an average of the air flow. Fans in a primary loop suck the air from the main stack and transport the air back to the main stack again. Three secondary loops are connected to the primary loop and transport the air at lower volume flow through parallel loops for sampling of aerosols, iodine, noble gases as well as equipment for collecting C-14 and tritium. The flows are chosen to achieve isokinetic conditions, which is a prerequisite for representative results. All of the analyses will not be required during the care and maintenance phase. The schematic description of the system is shown in figure 3-3.

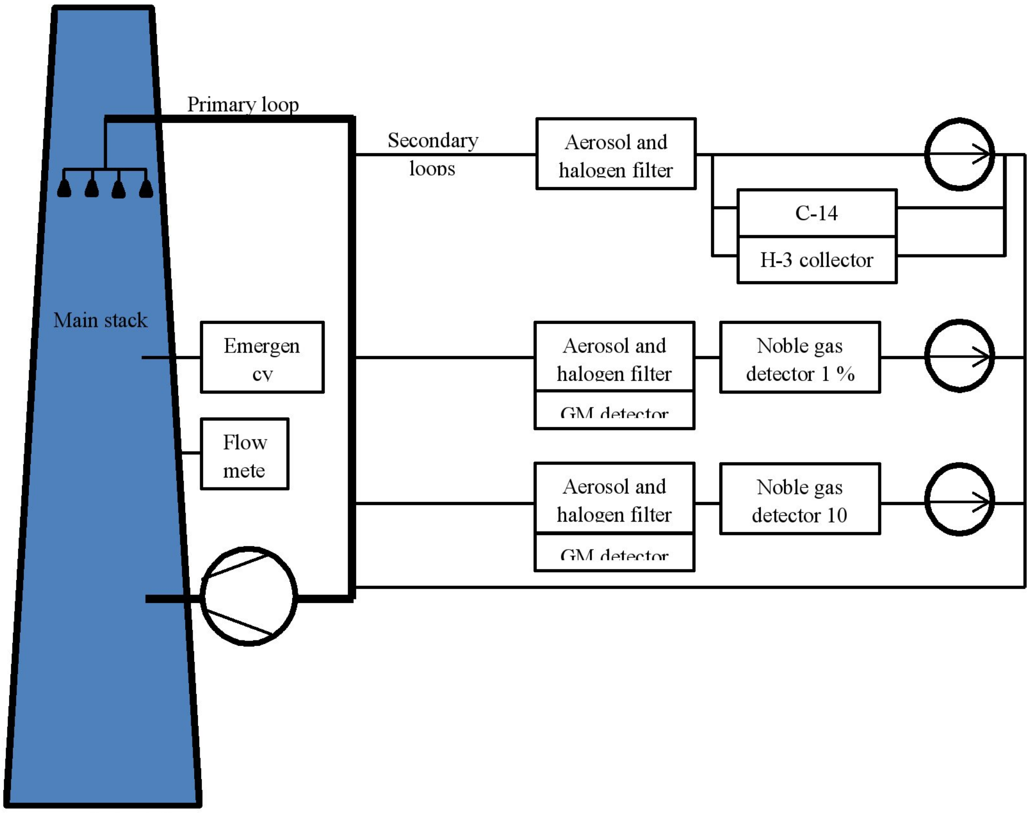

Figure 3-3. Schematic description of the activity monitoring system in the main stack in Oskarshamn 1 and 2. There are also flow meters in the primary and secondary loops.

Exemption from the requirements to continuously monitor noble gases and iodine in accordance with SSMFS 2008:23 [2] (see section 3.1) cannot be granted until all spent fuel elements have been transported to Clab.

Nuclide specific gamma analyses are conducted in the local chemistry laboratory, further information is given in section 3.3.2.

No external analyses of discharges are performed. However, inter-comparisons with SSM on aerosol filters are done on a regular basis. Also in the annual meetings with radiochemists at Swedish and Finnish nuclear power plants, inter-comparisons for e.g. nuclide specific measurements of alpha, beta and gamma radiations are performed. This increases the quality of the measurements and helps to identify areas for improvement. Internal inter-comparisons between the laboratories at OKG are also performed every year in accordance with an internal routine [23].

3.3.2 Principal features of the monitoring equipment

The most important sample collection and analyses that will be conducted during dismantling and demolition concern aerosols. In figure 3-4 the system containing the cartridges are shown in Oskarshamn 2. The collection of aerosols is continuous and the filters are usually replaced once a week. Together with the total volume that has passed through the filter and the average air flow in the main stack, it is possible to calculate the discharges of aerosols to air.

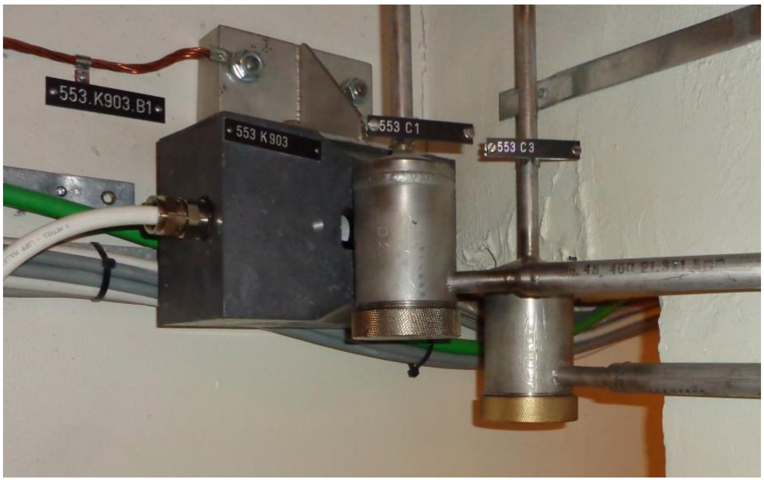

Figure 3-4. Sampling cartridge holder for aerosol sampling in Oskarshamn 2 (system 553). The equipment in Oskarshamn 1 has a similar design.

Figure 3-5. Aerosol filter used for activity monitoring in the main stacks in Oskarshamn 1 and 2.

The filters, see figure 3-5, are analysed by nuclide specific gamma measurements using High Purity Germanium (HPGe) detectors in the local laboratory. When short-lived nuclides are present, decay corrections are done for decay during collection, but there is no need for this during dismantling and demolition since only long-lived nuclides will be present in the filter. The filters will also be used for analyses of Sr-89/90 and alpha emitting nuclides.

The aerosol sampling is adjusted for losses during collection [24].

There is also mobile equipment available for specific tasks during dismantling and demolition. The main reason for using the equipment is occupational safety. The instrument measures airborne radioactivity, taking into account alpha and beta contamination. It has an alarm that will warn the personnel in case of airborne contamination.

Manual samples can also be taken using aerosol filter cartridges and air pumps. The filters are then analysed for nuclides specific gamma radiation as well as total alpha in the local laboratory.

3.3.3 Alarm levels and intervention actions

There are automatic alarms connected to the main control room (MCR) for:

- Low air flow in the main stack.
- Low flow in the sampling loops.

– High activity in the ventilation from the reactor hall (connected to the central control room, used for detecting fuel leakages during fuel handling).
– High activity in the GM-detectors (20 µSv/h and 100 µSv/h respectively, mainly for detecting iodine during power operation).

3.4 Evaluation of Transfer to Man

Section 3.4 covers discharges to both air and water.

If the assessed maximum exposure levels from discharges during normal conditions to adults, children and infants in the vicinity of the plant are below 0.01 mSv per year and there are no exceptional pathways of exposure, e.g. involving the export of foodstuff, no data on effective dose in other affected member states are required if doses to the reference group in the vicinity of the plant are provided.

The doses to the reference group in the vicinity of the plant during the dismantling and demolition phase are shown in figure 3-2 (discharges to air), figure 4-2 (discharges to water) and figure 0-4 (total discharge, see introduction).

The doses to the reference group are well below the specified limits. Any data on effective dose in other affected member states are thus not required.

3.4.1 Models, including where appropriate generic models, and parameter values used to calculate the consequences of the releases in the vicinity of the plant

The radioactive discharges (Bq) are converted into dose (mSv) for the theoretically most exposed individual in the reference group by multiplying the discharged radioactivity with reactor specific dose factors.

The current dose factors have been used since 2002. The dose is integrated over 50 years of normal power operation of the three reactors at the Simpevarp peninsula. The dose factors are reactor specific, i.e. the dose factors for Oskarshamn 1 and 2 are not the same, mainly due to different stack heights. There are no difference in dose factors for power operations and decommissioning.

Assumptions, calculations and data used for the model can be found in the following reports:

- Dose factors for discharges to water and air at normal power operation at OKG, STUDSVIK/ES-02/28 [25].
- Dose factors for normal discharges – A. Dispersion in air and ground deposition, STUDSVIK/ES-01/33 [26].
- Dose factors for normal discharges – B. Discharges to water, STUDSVIK/ES-01/34 [27].
- Dose factors for normal discharges – C. Exposure course and radio-ecological data, STUDSVIK/ES-01/35 [28].
- Dose factors for normal discharges – D. C-14 model, STUDSVIK/ES-01/36 (not mentioned further in this report since C-14 only is produced during power operation) [29].
- Dose factors for normal discharges – E. Area description and reference group, STUDSVIK/ES-01/37 [30].
- Dose factors for normal discharges – F. Method report, STUDSVIK/ES-01/38 [31].

At present, a review of the dose factors is in progress in Sweden. New dose factors will possibly be used from 2017 or 2018 in all Swedish nuclear power plants, but in this report the Studsvik method from 2002 and its dose factors are applied. The differences in dose factors between the present and the future models are small and will not affect the conclusions in this report.

The age groups in the reference group include:

- Infants 0-1 years.
- Infants 1-2 years.
- Children 2-7 years.
- Children 7-12 years.
- Children 12-17 years.
- Adults 18- years.

Data used in the models

Some important site-specific data are given in table 3-8.

Table 3-8. Site-specific data used in the models.

Sea average depth	9 m
Height of main stack Oskarshamn 1	70 m
Height of main stack Oskarshamn 2	110 m
Annual precipitation	675 mm
Average precipitation intensity	0.5 mm/h
Water outflow	0.18 $m^3/(m^2*year)$
Part of the year with pasturage	55 %
Home protection factor from ground radiation	0.3
Average temperature during plant-growing season	12.5 °C
Plant-growing season length	200 days
Annual production of grain	0.52 kg/m^2
Annual production of fodder grain	0.44 kg/m^2
Annual production of pasture ground	0.43 kg/m^2
Annual production of vegetables	2.9 kg/m^2
Annual production of root vegetables	4.13 kg/m^2

The dose factors for Co-60 in discharges to air from Oskarshamn 1 and 2 in mSv/Bq for infants 1-2 years, children 7-12 years and adults are specifically given in table 3-9, since they are used in the calculation of dose to the reference group in this report. Corresponding dose factors for Co-60 in discharges to water are shown in table 3-10.

Table 3-9. Dose factors for Co-60 in discharges to air from Oskarshamn 1 and 2 in mSv/Bq for infants of age 1-2 years, children 7-12 years and adults.

	Oskarshamn 1	**Oskarshamn 2**
Infants 1-2 years	2.92E-14	2.36E-14
Children 7-12 years	2.96E-14	2.39E-14
Adults 18- years	2.59E-14	2.10E-14

Table 3-10. Dose factors for Co-60 in discharges to water from Oskarshamn 1 and 2 in mSv/Bq for infants of age 1-2 years, children 7-12 years and adults.

	Oskarshamn 1 and 2
Infants 1-2 years	3.63E-15
Children 7-12 years	2.96E-15
Adults 18- years	9.26E-16

Exposure courses for discharges to water and air

Exposure courses that have been taken into account for discharges to water are time spent at the beach (all ages) and fish consumption (all ages except 0-1 years). Fish consumption gives almost 100 % of the dose.

Exposure courses that have been taken into account for discharges to air are:

- External dose due to exposure from clouds.
- External dose due to activity on the ground.
- Internal dose due to inhalation.
- Internal dose due to ingestion of:
  - vegetables
  - root vegetables
  - fruits
  - garden berries
  - grain
  - meat
  - milk
  - venison
  - mushrooms
  - wild berries.

The dose factor of the mother nuclide includes effects from the daughter nuclides if they significantly affect the dose received.

The main exposure courses vary for different nuclides, but are listed in STUDSVIK/ES-02/28 [25]. For Co-60 the main exposure course is through activity on the ground for all age groups.

More thorough investigation of the different exposure courses is given in STUDSVIK/ES-01/35 [28]. The dose factors are taken from 96/29/Euratom [32].

Dispersion in air and ground deposition

Phenomena that affect how activity discharged into the atmosphere is distributed include: wind direction and velocity, plume lift, rain, wet and dry deposition, degree of turbulent distribution, reflection of plume, dry deposition, influence by buildings and release heights, radioactive decay etc. The calculation methods are described in STUDSVIK/ES-01/33 [26].

In the report, average meteorological data for several years are used (wind velocity, wind direction, Pasquill class (affects the turbulence in different layers in the air). The wind direction has been divided in 10 degree sections, the wind velocity in groups of 2 m/s up to 16 m/s. Subsequently, plume values for all these different combinations of data have been calculated, in combination with the frequency for the specific conditions.

Measuring or calculating actual concentrations in the air and ground activity is a difficult task, and some assumptions have to be made in the modelling:

- The wind velocity is measured at a height of 10 m instead of the height of the discharge.
- The plume depletion due to deposition is negligible.
- The effects by the building are not included.
- The plume lift is not taken into consideration.

These assumptions will give an overestimation of a factor of 9 according to STUDSVIK/ES-01/33 [26]. Wind directions with frequencies and velocities Pasquill classes are discussed in section 1.3.

Discharges to water

Discharges to water are done in a batched process, where the radioactive waste water is dispersed into the large volume of cooling water used by the power plant in operation. Since Oskarshamn 3 will still be in operation, the discharges will be diluted and distributed to the Baltic Sea as before. In the model, the discharges are evenly distributed over the year. The areas are described by boxes with certain volumes and water renewal times. The sediments are described using two boxes; one for the top layer and one for the lower layer (less exposed to resuspension and biological processes). The water renewal is high, so the discharges are efficiently mixed with the surrounding waters.

The volume of the boxes is determined with respect to the fish territories together with information about the cooling water spread-out plume. In the model used for Simpevarp only one rectangular box is used, with a length of 5 km and a width of 2.5 km. The model in STUDSVIK/ES-01/34 [27] describes how radionuclides are released, how they are adsorbed on particles and transferred to surrounding sediments, how they are re-suspended back into the water, what factors dominate the uncertainties of the model, and the like. There are parameter values for e.g. annual sediment growth, sinking velocity for particles and amounts of suspended material.

Human habits affecting the dose factors

In STUDSVIK/ES-01/35 [28] information regarding e.g. human diets is included. The people in the reference group are assumed to only eat locally produced food (meat, fish, vegetables, root vegetables, fruit, berries, grain and milk). From a dose perspective, this assumption overestimates the dose. The consumption of food mirrors an average Swede according to the national food agency in Sweden.

Different breathing frequencies and amount of food consumed are used for the different age groups when calculating the dose factors, for more information see STUDSVIK/ES-01/35 [28]. As an example: children tend to drink more milk than adults.

Area description and distance to reference group and different foodstuff

OKG is located near the villages Figeholm (1,000 inhabitants), Fårbo (500), and Misterhult (200). The municipality of Oskarshamn has 27,000 inhabitants and approximately 70 % lives in the town Oskarshamn, located 20 km south-east of Simpevarp. The area of the entire municipality is approximately 1,050 km^2. In the Kalmar district 2/3 of the area is woodland. Cultivated ground constitutes 12 % of the total area. STUDSVIK/ES-01/37 [30] specifies how large areas are used for different kinds of crops, dominated by pasture ground (49 %) and fodder crops (27 %).

The closest all-the-year-round home is in Ekerum (1 km north-west of Simpevarp, 13 houses). In the model the beef cows in Ström (3 km west of Simpevarp) are used, although in recent years there have been problems with obtaining meat samples for the environmental monitoring programme. The closest milk cow farm is in Basthult (5 km west-northwest of Simpevarp). Sheep graze in the old village at the Simpevarp peninsula. The closest grain grower is in Ekerum.

3.4.2 Evaluation of the concentration and exposure levels associated with the envisaged discharge limits for the dismantling operations cited in 3.1 above

No calculations of the concentrations have been performed specifically for the decommissioning of Oskarshamn 1 and 2. Having three nuclear reactors in operation is estimated to give higher doses to the reference group than the dismantling and demolition of Oskarshamn 1 and 2.

The annual exposure for the reference group (infants, children and adults) is discussed in section 3.2

The annual average concentration of activity in the atmosphere near the ground (fBq/m^3) as well as annual precipitation (nBq/m^2) as a function of the amount of discharged activity is calculated in STUDSVIK/ES-01/37 [30], see figures 3-6 and 3-7.

Figure 3-6. Calculated annual average concentration in air (fBq/m^3) from discharge of 1 Bq, released at 70 m, i.e. from Oskarshamn 1 [30].

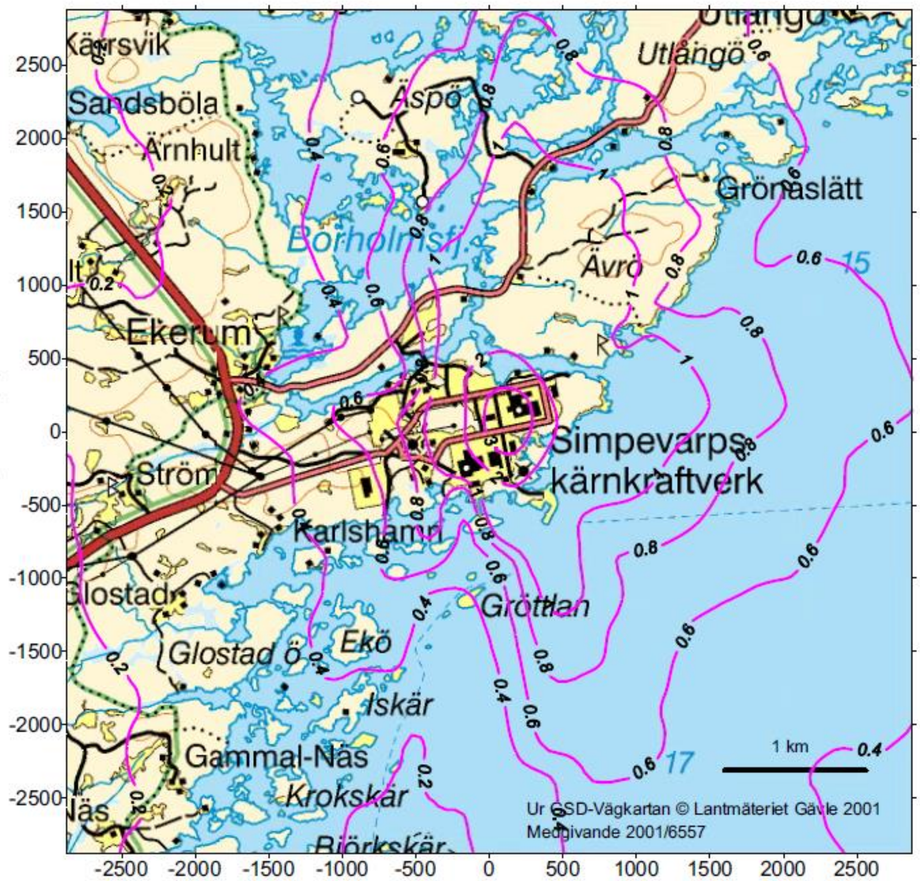

Figure 3-7. Calculated annual precipitation from discharge of 1 Bq to air (nBq/m²) from discharge of 1 Bq, released at 70 m, i.e. from Oskarshamn 1 [30].

If 1.8E+08 Bq of Co-60 is released (see data for the year 2019 in figure 3-1) the calculated concentration on the ground 1 km north-northeast of Simpevarp will be 1 µBq/m^3. Precipitation in the middle of the plant will be 0.5 Bq/m^2.

For 2015 the average concentration of Co-60 in the discharge water was 16 Bq/kg. This amount is diluted by the cooling water from the power plants, currently 20 m^3/s for Oskarshamn 1 and 57 m^3/s for Oskarshamn 3.

The activity follows the plume for the spread of heated cooling water illustrated in figure 1-7.

4 Release from the Installation of Liquid Radioactive Effluents in Normal Conditions

Information valid for both air and water discharge is given in more detail in section 3. In this section, only the aspects specific for water discharges are described.

4.1 Authorisation Procedure in Force

Oskarshamn 1 and 2 have a common waste facility for handling liquid waste waters. The reference and target values are accounted for together.

Table 4-1. Reference values in Bq for 2004-2021, discharges to water from Oskarshamn 1 and 2.

Nuclide/group	2011	2016	2021
Total activity	4.7E+09	-	-
Co-60	3.1E+09	4.0E+08	2.0E+08
Cs-137	5.2E+07	1.0E+07	1.0E+07

Table 4-2. Target values in Bq for 2004-2021, discharges to water from Oskarshamn 1 and 2.

Nuclide/group	2011	2016	2021
Total activity	1.0E+09	-	-
Co-60	7.0E+08	2.0E+08	1.5E+08
Cs-137	1.0E+07	1.0E+07	1.0E+07

The dose from discharges of radioactivity to water is dominated by Co-60 and Ag-110m. Since Ag-110m has a comparatively short half-life (250 days) focus in this report will be on Co-60. Cs-137 gives a factor 100 less in dose than Co-60 (data from 2016).

There are no specific limits for the time before the envisaged dismantling operations or the dismantling operations themselves. As for discharges to air, the requirements in SSMFS 2008:23 [2] constitute the basis for further analyses.

4.2 Technical Aspects

4.2.1 Annual discharges expected during dismantling

Discharges to water during dismantling and demolition will not be affected in the same manner as discharges to air by the activities performed in the facilities. The most important factor when it comes to preventing discharges to water is to keep the volume of the incoming water low. Less water arriving to the waste clean-up process allows more efficient cleaning of the waste water before discharge.

Once Oskarshamn 1 has been shut down the make-up water for process losses will result in more than 50 % less water arriving to the waste clean-up process. This has not been taken into account when estimating the discharges and doses during the dismantling and demolition.

2004/2/Euratom [17] specifies the nuclides that must be reported from nuclear facilities in discharges to air and water. In discharges to water, Fe-55 and Ni-63 are analysed and reported. In Bq they are quite common, but as they are weak beta emitting nuclides the dose factors are low and thus they will not affect the dose to the reference group. Other hard-to-measure nuclides that are reported are Sr-89/90 and alpha emitting nuclides.

The expected discharges of Co-60 to water from Oskarshamn 1 and 2 together with the actual discharged activities are shown in figure 4-1 and table 4-1.

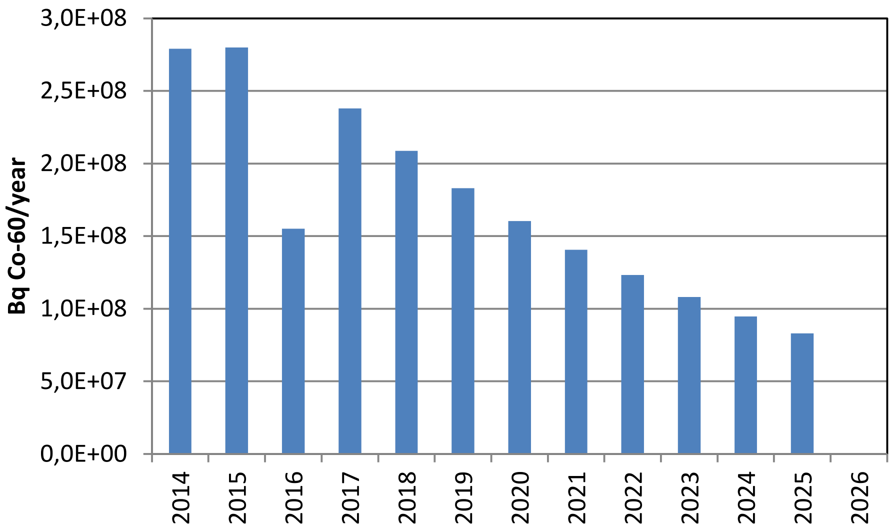

Figure 4-1. Discharges of Co-60 to water from Oskarshamn 1 and 2.

Table 4-3. Estimated discharges of Co-60 in Bq to water from Oskarshamn 1 and 2.

Year	Co-60 (Bq)
2017	2.38E+08
2018	2.09E+08
2019	1.83E+08
2020	1.60E+08
2021	1.41E+08
2022	1.23E+08
2023	1.08E+08
2024	9.48E+07
2025	8.31E+07
2026	0

The discharge level for 2017 is calculated as the average amount in 2014-2016. It is assumed that the same amount is discharged every year during dismantling and demolition, only taking decay correction into account. The discharges will probably be overestimated since less water will arrive to the waste clean-up process.

The full scale chemical decontaminations planned in 2019 for Oskarshamn 2 and in 2020 for Oskarshamn 1 will not significantly affect the discharges to water. The waste will be taken care of by ion exchange resins and be decomposed of as solid waste.

The estimated doses to the reference group (divided into subgroups for infants age 1-2 years, children 7-1 years and adult) are given in figure 4-2 and table App 2-2 (in Appendix 2). During dismantling and demolition children 7-12 years will be the most affected age group from discharges to water.

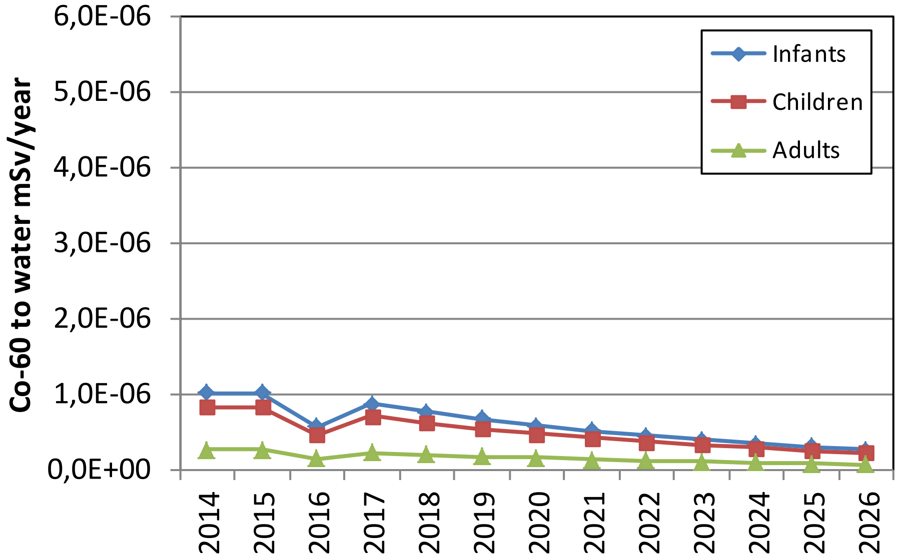

Figure 4-2. Estimated dose from Co-60 discharges to water from Oskarshamn 1 and 2 for infants age 1-2 years, children 7-12 years and adults. Data can be found in Appendix 2.

During power operation, the dose is dominated by C-14. The annual dose from OKG received by children age 7-12 years in the last years of operation was approximately 2E-04 mSv/year, see figure 8-2.

The reference group will thus not receive higher dose from the dismantling and demolition of Oskarshamn 1 and 2 compared to what they receive during normal power operation.

For a child age 7-12 years to receive 10 µSv/year (0.01 mSv/year) from discharges of Co-60 to water from Oskarshamn 1 and 2, 3.4E+12 Bq would have to be released. The expected discharge of Co-60 is more than a factor 10,000 less.

4.3 Monitoring of Discharges

It is important to separate waters with a lot of radioactivity from waters with high ionic content to have an efficient cleaning before discharge.

Water that is to be discharged from Oskarshamn 1 and 2 is collected in discharge tanks (see line 6 in figure 2-3 in section 2.3). The water is analysed with respect to the gamma emitting nuclides and total alpha activity. During the discharge a proportional sample is collected, which is used for the official discharge analyses. All samples from one month are mixed into a monthly sample that is analysed regarding nuclide specific gamma and tritium. The monthly samples are mixed to a quarterly sample that is analysed for Fe-55, Ni-63, Sr-89/90 and alpha emitting nuclides.

4.4 Evaluation of Transfer to Man

Section 3.4 covers evaluation of transfer to man from discharges to both air and water.

5 Disposal of Solid Radioactive Waste from the Installation

5.1 Solid Radioactive Wastes

The licensees are responsible for the nuclear waste arising during operation and decommissioning. This responsibility ceases once the waste has been placed in a final repository that has been finally sealed.

In addition to chapter 2.4 this section provides information about the end-state alternatives that OKG is expected to use in order to manage the radioactive solid waste arising from the decommissioning of Oskarshamn 1 and 2 and the waste handling building 0AVF.

5.1.1 Alternative End-states

The system for handling waste in Sweden is described in sections 2.4-2.5 and appendix 3.

There are generally to two different end-states for the radioactive waste with exception for the ILW and HLW. The different alternatives can be classified as clearance or disposal.

Clearance

In Sweden there are two types of clearance – general and conditional.

General clearance entails that material and waste can be reused, recycled or deposited without any radiological requirements. General clearance as per SSMFS 2011:2 [33] applies to clearance levels for free use. The clearance limit in Sweden is 0.1 Bq/g for Co-60.

Waste and material may be subject to conditional clearance in accordance with special conditions. Sand and concrete can for instance be recycled for road construction, metal may be recycled to the metal industry or waste can be disposed on a hazardous waste disposal site. This type of clearance requires that the certain condition in the regulation is met and that special permission by the Swedish Radiation Safety Authority is granted. Conditional clearance as per SSMFS 2011:2 [33] applies to some levels of hazardous waste and the clearance limit for Co-60 is 1 Bq/g.

Disposal as solid radioactive material and waste

In Sweden there are a few alternative disposal methods for radioactive materials and waste, such as landfills, owned and managed on site for very low level active waste. The dose rate must be lower than 0.5 mSv/h and the requirements on the nuclide specific activity concentrations must be met. Both compactable and non-compactable waste can be deposited in this repository. The waste must be kept in the landfills for nearly 75 years and by that time most of the radioactivity will have decayed and the waste and material in the landfill will be considered as a disposal of conventional waste.

Sweden has a geological repository for short-lived low and intermediate level radioactive waste (SFR), provided by SKB AB, for final disposal. In order to have sufficient capacity in SFR, it is planned to be extended. An application was handed in 2014 and is presently being reviewed. In the meantime up until the extension is completed, low level and intermediate level waste are temporarily stored in an interim storage on site, until the year 2030 for the short-lived low and intermediate level waste,.

For long-lived low level and intermediate level radioactive waste, a geological repository (SFL) is planned to be in operation 2045. Thus, long-lived radioactive waste has to be stored until 2045.

A specific description of the waste handling process from the time it is produced until it has been finally deposited in SFR and SFL is required [12]. In the waste type descriptions (WTD) the waste acceptance criteria (WAC) are presented together with a description on how the WAC:s are verified. Before a certain waste type can be produced and disposed of at the SFR-facility, the WTD must be approved by the Swedish Radiation Safety Authority.

5.1.2 Waste Led Decommissioning

Most licensees of nuclear facilities consider the management of the radioactive or potentially radioactive waste as one of the most critical aspects of the decommissioning planning or ongoing decommissioning activities. A strategic and structurally adapted approach to reduce the risk related to waste management is to perform a Waste Led Decommissioning (WLD).

A key principle in WLD is that it is mandatory to develop a plan for the materials and waste prior to any dismantling and demolition activities. A frequent and fast removal of material and waste will increase the performance in the decommissioning project. WLD also has zero tolerance for waste routes without defined and accepted disposition routes. Reconditioning is expensive concerning both radiation dose and cost. By applying WLD, it is possible to perform the work correctly from the start. All radioactive, and potentially radioactive, materials and waste must immediately be registered in accordance with well-defined procedures. There should be quality assurance and traceability throughout the process until final disposal (confirmed end-state).

5.1.3 Waste categorization

The initial categorization of materials, buildings and site areas from a radiological and hazardous perspective as well as estimated volumes and weights are taken from existing decommissioning studies [34]. In order to establish a foundation, it is important to take operational history into account.

One of the most important decisions concerns the setting of the boundary for extremely small risks of contamination. OKG will comply with the recommendation and guideline for clearance [35]. An example of how to categorize solid waste from a radiological perspective is given in table 5-1 below. LLW is graded into four levels of activity, in order to plan and forecast the waste management in a more realistic manner based on safety and time efficiency.

Table 5-1. Categorization parameters for Swedish conditions (Bq/g Co-60).

Waste category	**Specific activity content [Bq/g Co-60]**
Extremely low risk	Contamination ***cannot*** occur
Low risk	Contamination of significance for clearance ***should not*** occur
Risk	< 0.1
LLW-1	0.1 – 1
LLW-2	1 – 20
LLW-3	20 – 100
LLW-4	100 – 1 000
ILW	> 1 000

By taking into account the benefits of the decommissioning studies [34], operational records and other relevant information, the materials and waste during the dismantling and demolition were categorized and quantified,

Table 5-2 shows the total amount of the masses of each waste category for Oskarshamn 1 and 2 and the waste handling building (0AVF) and is presented in figure 5-1.

Table 5-2. Total amount of solid radioactive waste per category for Oskarshamn 1 and 2 and the waste management building 0AVF.

Waste category	**Total [ton]**
Extremely low risk	221,400
Low risk	Not quantified
Risk	11,400
LLW-1	6,540
LLW-2	1,350
LLW-3	997
LLW-4	1,805
ILW	2,440
Total	246,237

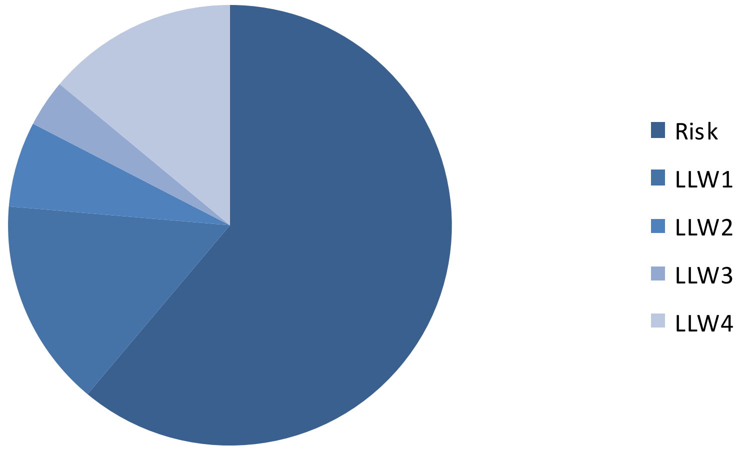

Figure 5-1. Total amount of low level radioactive solid waste per activity category Risk-LLW for Oskarshamn 1 and 2 and the waste handling building 0AVF.

5.1.4 Solid radioactive waste from Oskarshamn 1

In accordance with the end-state alternatives and the results of waste categorization, the material and waste can be placed in different waste streams: *Large components, Metal, Compactable/Combustible* and *Other radioactive solid waste (concrete/sand/biological shield)* in order to obtain a more efficient waste management. The volume of radioactive solid waste of the waste handling building is included in the volume of Oskarshamn 1.

The asterisk (*) in the Tables 5-3 to 5-10 below refers to the uncertainty in volume/masses in the category until an updated characterization for accurate quantification is available. The total volumes are more correct but volume per category will probably change as per an updated characterization. The limits of the activity for categories have been developed since the decommissioning studies [34] were performed in 2013, which is one reason why the volumes and masses are shown as an asterisk in the Low Risk category. When an updated characterization is available, part of the volumes and masses in category Risk may be placed in Low Risk but until then, it is a well-known strategy to place it in a higher category because it is better to handle it as more radioactive.

Large components

The definition of Large components refers to components with a weight of more than 20 ton and which cannot be placed and transported in a 20” container.

Table 5-3. The amount of large components at Oskarshamn 1.

Waste category	Weight (ton)	Number
Extremely low risk	*	*
Low risk	*	*
Risk	1,400	8
LLW-1	800	9
LLW-2	180	12
LLW-3	470	9
LLW-4	150	7
ILW	410	1

Metal

The metal waste is comprised of both long-lived and short-lived radioactive material and waste, where the long-lived material solely consists of internal parts that have been neutron activated. The difference between metal and large components is the way it is treated and handled.

The metal waste originates from:

- Process systems.
- Steel structures.
- Ventilation systems.
- Electric equipment.

Table 5-4. The amount of metal at Oskarshamn 1.

Waste category	Weight (ton)
Extremely low risk	1,900
Low risk	*
Risk	3,500
LLW-1	1,800
LLW-2	160
LLW-3	240
LLW-4	210
ILW	340

Combustible/Compactable

The amount of combustible/compactable waste is estimated based on experiences from two German decommissioning projects (Stade and ISAR 1). During the decommissioning, this will generate more waste than stated in the table below due to secondary waste arising from the various treatments and work practices (e.g. clothes, hand gloves, plastic).

Table 5-5. The amount of combustible/compactable waste at Oskarshamn 1.

Waste category	Weight (ton)
Extremely low risk	*
Low risk	*
Risk	50
LLW-1	40
LLW-2	25
LLW-3	25
LLW-4	5
ILW	5

Other solid waste

Other radioactive solid waste is comprised of concrete and sand. Concrete is present in conventional building material and as radiation protection of the biological shield. Concrete in the category ILW comes solely from the biological shield. The rest of the concrete in the category ILW concerns concrete from the waste handling building (0AVF). The majority of concrete waste will be crushed into small parts.

Sand from the waste gaseous system contributes with 420 ton of waste, including about 25 % contaminated sand with noble gas daughters. The contaminated sand has an average specific activity of 1.2E+3 Bq/g.

Table 5-6. Amount of waste from concrete and sand at Oskarshamn 1.

Waste category	**Weight sand (ton)**	**Weight concrete (ton)**	**Weight Biological shield (ton)**	**Weight Total (ton)**
Extremely low risk	*	82,000	*	**82,000**
Low risk	*	*	*	*****
Risk	*	*	*	*****
LLW-1	320	*	240	**560**
LLW-2	*	*	*	*****
LLW-3	110	*	*	**110**
LLW-4	*	250	270	**520**
ILW	*	100	270	**370**
Total	**430**	**82,350**	**780**	**83,560**

5.1.5 Solid radioactive waste from Oskarshamn 2

The waste categorization for Oskarshamn 2 is the same as for Oskarshamn 1.

Large components

The definition of large components refers to components with a weight of more than 20 ton and which cannot be placed/transported in a 20” container.

Table 5-7. Amount of large components at Oskarshamn 2.

Waste category	**Weight (ton)**	**Number**
Extremely low risk	*	*
Low risk	*	*
Risk	1,630	20
LLW-1	*	*
LLW-2	440	9
LLW-3	55	1
LLW-4	*	*
ILW	580	2

Metal

The metal waste is comprised of both long-lived and short-lived radioactive material and waste, where the long-lived material solely consists of internal parts that have been neutron activated. The difference between metal and large components is the way it is treated and handled

The metal waste originates from:

- Process systems.
- Steel structures.
- Ventilation systems.
- Electric equipment

Table 5-8. Amount of metal at Oskarshamn 2.

Waste category	**Weight (ton)**
Extremely low risk	2,500
Low risk	*
Risk	4,600
LLW-1	2,100
LLW-2	210
LLW-3	72
LLW-4	490
ILW	420

Combustable/Compactable

The amount of combustible/compactable waste is estimated based on experiences from two German decommissioning projects (Stade and ISAR 1). During the decommissioning, this will generate more waste than stated in the table below due to secondary waste arising from the various treatments and work practices (e.g. clothes, hand gloves, plastic).

Table 5-9. Amount of combustible/compactable at Oskarshamn 2.

Waste category	Weight (ton)
Extremely low risk	*
Low risk	*
Risk	50
LLW-1	40
LLW-2	25
LLW-3	25
LLW-4	5
ILW	5

Other solid waste

Other radioactive solid waste is comprised of concrete and sand at Oskarshamn 2. Concrete is present in conventional building material and as radiation protection in the biological shield. Concrete in the category ILW is solely from the biological shield.

Sand from the waste gaseous system contributes with 1,550 tons of waste including about 25 % contaminated sand with noble gas daughters. The contaminated sand has an average specific activity of 1.7E+2 Bq/g.

Table 5-10. Amount of other solid waste at Oskarshamn 2.

Waste category	Weight sand (ton)	Weight concrete (ton)	Weight Biological shield (ton)	Weight Total (ton)
Extremely low risk	*	135,000	*	**135,000**
Low risk	*	*	*	*****
Risk	*	*	*	*****
LLW-1	1,200	*	*	**1,200**
LLW-2	*	240	240	**480**
LLW-3	*	*	*	*****
LLW-4	390	*	340	**730**
ILW	*	*	310	**310**
Total	**1,590**	**135,240**	**890**	**137,720**

5.1.6 Alternative Waste Routes

Based on the waste streams and the alternative end-states, four alternative waste routes were identified and analysed. All waste routes were found to be acceptable, as long as the waste acceptance criteria for the alternative are met. Se figure 2-5 and appendix 3 for more information of the Swedish system in addition to the description below.

Geological disposal with treatment on-site or off-site

All large components have to be segmented and in some cases melted for volume reduction. The rest of waste categories will be conditioned to be disposed in a geological repository (SFR/SFL). The components which can be segmented on site will be handled locally, but some components must be sent for external treatment. For treatment on site there are two alternatives, inside the facility or outside the facility. Since SFR is not expected to be available during the demolition and dismantling, all radioactive solid waste must be placed in an interim storage for more than a decade. SFL will not be available until 2045.

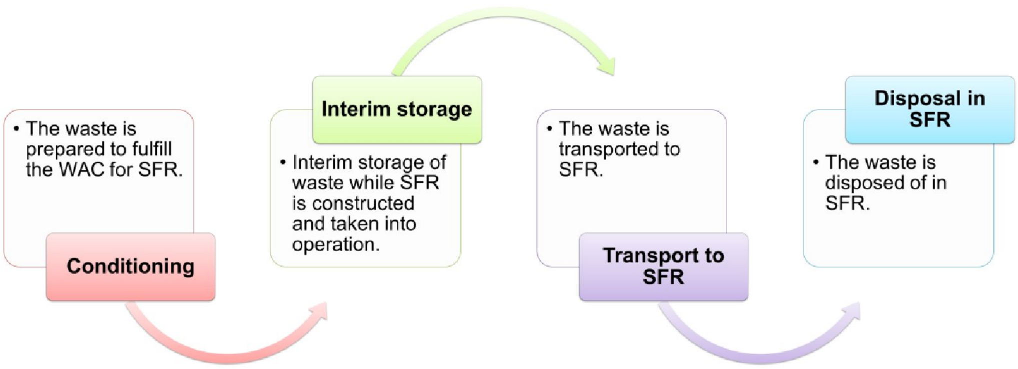

Figure 5-2. Management of geological disposal.

Off-site treatment for volume reduction or clearance

Most of the material and waste in this category will be sent to an external treatment facility, located in Studsvik, for further processing such as melting for clearance and volume reduction. Waste targeted for this waste route refers for example to large components, metal in low level categories and combustible waste. Produced residual waste will be stored at the Studsvik site until final disposal in SFR or SFL. Other material is governed essentially by clearance or volume reduction to reduce the need for final storage capacity.

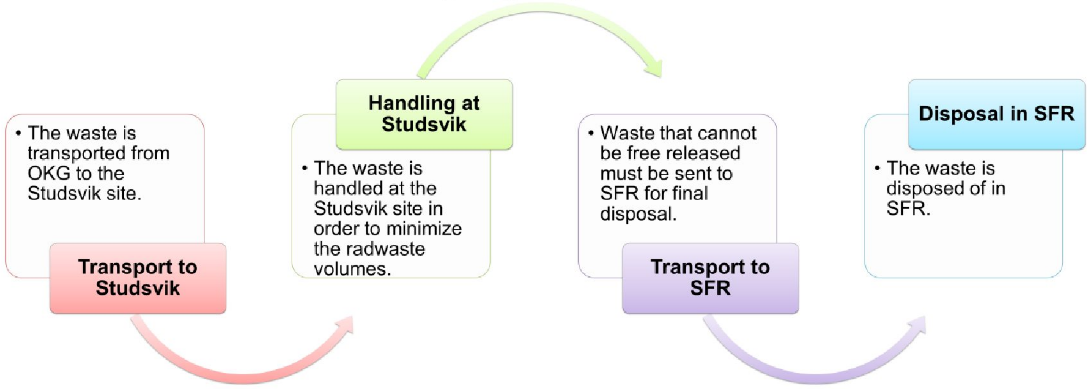

Figure 5-3. Management of off-site management.

Landfill (surface repository or land disposal)

Since large components are not allowed in the landfill, they will either be subject to clearance on site or undergo external treatment for clearance or volume reduction. They will only be a target for this waste route if they are melted for volume reduction. The residual waste from the treatment and the ingots will be placed in the landfill. All other materials and waste with dose rates up to 0.3 mSv/h (OKG internal requirements, license states 0.5 mSv/h) which comply with the requirements of the nuclide specific limits, are disposed of in a landfill on site. The existing landfill is almost full and is only licensed for operational waste. OKG has initiated a project for a new landfill (MLA3), planned to be licensed for both operational and decommissioning waste.

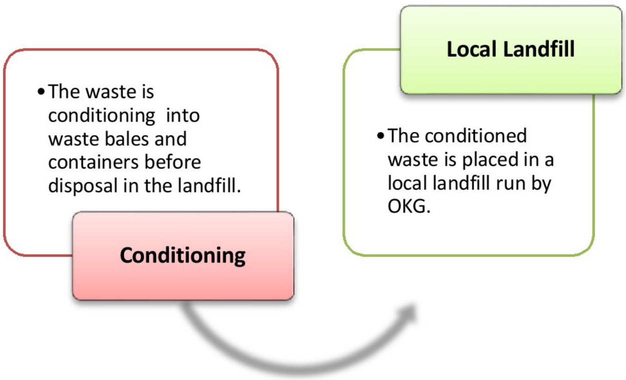

Figure 5-4. Management of landfill.

Clearance

Clearance of materials, either directly or after some kind of treatment. A waste treatment area is required, installed with segmentations and decontamination options are required within the existing buildings or elsewhere on site, but a new area for the clearance process will also be required, in an existing building or in a new one. Large components can be handled on site or be sent to an external treatment area for further general or conditional clearance. Metal within the dose rate < 0.1 mSv/h can be a target for external treatment for further general clearance or conditional clearance.

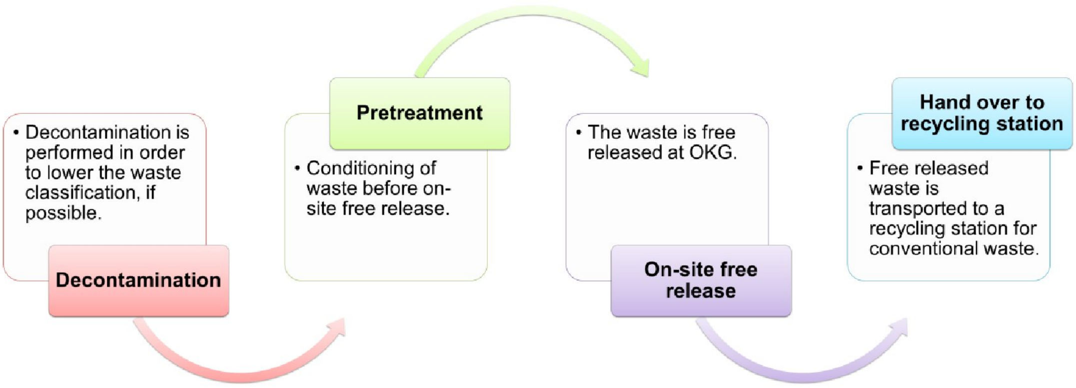

Figure 5-5. Management of local clearance.

More than one of the alternative waste routes may be relevant for several of the waste streams. OKG's waste management strategy also points out the value of keeping more than one of these waste routes available during the decommissioning process. Redundancy by keeping two, or sometimes three, waste routes available in addition to a primary waste route is considered as good practice and motives for redundancy are based on logistics, radiation protection, environmental impact and risks. Some waste streams, mainly in the ILW category, have just one possible waste route to apply, but for other waste streams the redundancy can mitigate both risks and bottle necks.

Table 5-11. Waste route alternatives compared with the categorized waste streams.

	Local clearance + Conventional recycling	Landfill OKG	Off-site treatment	SFR/SFL	
Risk					*Up to 0.1 Bq/g Co-60*
Large components	x		x	(x)*	
Metal	x	x	x	x	
Combustible		x	x	x	
Other solid waste	x	x	x	x	
LLW-1					*0.1-1 Bq/g Co-60*
Large components	x		x	(x)*	
Metal	x	x	x	x	
Combustible		x	x	x	
Other solid waste	x	x	x	x	
LLW-2					*1-20 Bq/g Co-60*
Large components	x		x	(x)*	
Metal	x	x	x	x	
Combustible		x	x	x	
Other solid waste		x	x	x	
LLW-3					*20-100 Bq/g Co-60*
Large components			x	(x)*	
Metal		x	x	x	
Combustible		x	x	x	
Other solid waste		x		x	
LLW-4					*100-1000 Bq/g Co-60 <2 mSv/h*
Large components			x	(x)*	
Metal			x	x	
Combustible			x	x	
Other solid waste				x	
ILW					*>1000 Bq/g Co-60 >2 mSv/h*
Large components				(x)*	
Metal				x	
Combustible				x	
Other solid waste				x	

**At present, it is unusual to dispose large components in SFR but this is currently being looked into and may be an option in the extended SFR.*

It is considered important to keep focus on the total decommissioning project, in order to meet the wanted end-state. Uncertainties related to waste disposal must not be underestimated and should be mitigated. Inadequacies in the waste management may affect costs and time schedule. Thus, redundancy in waste routes is considered a prerequisite for a successful overall decommissioning project.

5.1.7 Interim storage

BFA – Bedrock depository for active waste

BFA is described as a facility in section 2.4.1.2 and it is used as OKG's interim storage for low and intermediate level active waste and other active material. Conditioned waste as well as waste that is not finally conditioned will be stored in BFA, awaiting further transportation to SFR/SFL. This is also the place where the nuclide specific gamma spectroscopy measurements of the LLW and ILW-waste are done, required for the disposal in either SFR or SFL.

Potential types of waste in this type of storage are:

- Moulds with intermediate level active ion exchange resin.
- Moulds with intermediate level compactable/non-compactable waste.
- Concrete tanks with lower level ion exchange resin.
- Concrete tanks containing surface contaminated waste.
- Steel tanks containing neutron-activated waste.
- Steel boxes with e.g. secondary waste from segmentation of internal parts.

Due to the extension of the SFR building and the fact that SFL will not be in operation before 2045, OKG has to ensure the capacity of the interim storage area in BFA. By calculations and investigations performed, OKG has concluded that the capacity in BFA will be sufficient for the generated waste until the beginning of 2045.

LLA – Interim storage of Low Level Waste

LLA as a facility is described in section 2.4.1.2, and it is used as OKG's interim storage of low level active waste and other active components and material. Conditioned waste as well as unconditioned waste will be stored in LLA, awaiting further transportation to the Studsvik site for external treatment like melting, to the landfill on site or to SFR. This is also the place where the nuclide specific gamma spectroscopy measurements nuclides of the stored waste are done, required for the disposal in both the landfill and in SFR.

LLA is planned to be extended or a new building will be built next to the existing interim storage building.

Potential types of waste in this type of storage are:

- Containers with non-compactable waste.
- Containers with compacted bales of compactable waste.
- Large component storage prior to further treatment and transportation.

5.2 Radiological Risks to the Environment

Risks to the environment during decommission from a radiological point of view consists of releases during the handling of radioactive components and materials and accidents in the plant, for instance fire or leakage of radioactive water. Risk analysis is found in chapter 6 in this report.

In order to prevent impact on the environment, precautions are taken, detection of releases (to water or air), controlled ventilation and detection of fires are examples of systems (either systems already in place or new temporary solutions) that will continue being used during dismantling. Furthermore, the interim storages on site will be monitored to the extent necessary depending on the type of waste stored. The expanded repository for low and intermediate level waste SFR is planned to open in 2030, which entails that it is necessary to store both low level waste and intermediate level waste on site until SFR is in operation.

The waste to be handled during the dismantling process consists of various radioactive components and materials. In order to reduce the activity level within the two units to the extent possible early in the process, the first dismantling step will concern segmentation of reactor the internal parts.

The material consists primarily of stainless steel. There are small quantities of nickel alloys in certain components such as the core spray distributors. The waste is also comprised of a small quantity of secondary waste that arises in conjunction with the segmentation of the internal parts of the reactor and filtering of the pool water. The quantity of radioactive waste in the project of segmentation of internal parts is estimated at approximately 250 ton. The waste will be distributed in approximately 80-90 steel or concrete tanks, where approximately half of the number of generated tanks will be steel tanks containing neutron-activated internal parts and the other half of the number of tanks, concrete tanks, will mostly contain internal parts which are more surface-contaminated than neutron-activated.. The transportation and interim storage of loaded steel tanks or concrete tanks are not expected to pose any significant radiological risks to the environment based on the above requirements being met.

5.3 Off-site Arrangements for the Transfer of Waste

During decommissioning of a nuclear facility, a large amount of waste and material have to be managed. The experience from international projects in this step is that the management system is a key factor in the operation of the project. Ideally all the material and waste should leave the site as early in the process as possible. If this is not possible, the waste must be placed in an interim storage on site due to logistical reasons, but at a distance from the facility being decommissioned.

Shipments of radioactive waste must comply with the requirements stipulated in the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) and the International Maritime Dangerous Goods Code (IMDG) [10-11]. The Swedish nuclear industry has an established transportation system, based on transport by SKB's ship m/s Sigrid, see figure 2-5. The transportation system is established for the operational waste and OKG will use the same kind of packages used for conditioning of waste. This entails that the SKB transportation system may be used for decommissioning waste as well. The transportation container for concrete and steel tanks with SFL waste is under development and is not yet available as a part of the system. OKG intends to store SFL waste in BFA until 2045.

The Studsvik site, where the external treatment facility is located, is a possible recipient for some of the waste. For transportation to/from to the Studsviks site, the industry can use both the sea route system and the roadway system.

5.4 Release of Materials from the Requirements of the Basic Safety Standards

SSM has issued regulations concerning the clearance of material, rooms, buildings and land used in activities involving ionising radiation, SSMFS 2011:2 [33]. The objective of the regulation is to, with due regard to radiological protection enable rational processing and use of materials, rooms, buildings and land that could have been contaminated with radioactive substances from activities involving ionizing radiation.

The clearance levels are established in the following sections of the regulations:

Section 11 The clearance level for radioactive contamination on the surface of a material amounts to 40 kilobecquerel per square metre for the beta- and gamma-emitting radionuclides that are the most common in the practice, calculated as a mean value over a maximum area of 0.03 square metres. The clearance level for alpha-emitting radionuclides in the practice amounts to 4 kilobecquerel per square metre, calculated as a mean value over a maximum area of 0.03 square metres. For clearance of objects smaller than 0.03 square metres, 0.03 square metres may be used as the total area for calculation of the mean value of surface contamination.

The clearance levels stated in the first paragraph are not applicable to liquids, finely dispersed materials nor other materials lacking a surface that can be checked.

Section 12 As far as concerns materials other than those covered by Sections 13 and 14, the clearance levels stated in Section 11 for radioactive contamination on surfaces shall be applied to the extent that these levels are applicable. Beyond this, the clearance levels provided in Appendix 1 shall be applied as shown in Appendix 4 for the concentration of radioactive substances.

Section 13 For used oil sent for incineration and hazardous waste sent for incineration or disposal, the clearance levels of Section 11 for radioactive contamination on surfaces shall be applied to the extent that these levels are applicable. Beyond this, the clearance levels provided in Appendix 2 shall be applied as shown in Appendix 4 for the concentration of radioactive substances.

Section 14 The clearance levels as stated for radioactive contamination on surfaces under Section 11 apply to tools and equipment used temporarily in the practice involving ionising radiation

and which, after their clearance, are intended to be used in another practice provided that:
1. the objects may only have been contaminated on the surfaces accessible for checks for contamination, and
2. the total contamination by radioactive substances does not exceed the exemption levels for total activity in accordance with Section 2, first paragraph, item 1 of the Radiation Protection Ordinance.

Section 15 As far as concerns rooms and buildings, the clearance levels provided in Appendix 3 shall be applied as shown in Appendix 4.

Section 16 Clearance levels for land are decided by the Swedish Radiation Safety Authority on a case-by-case basis.

The Appendixes 1 and 4 of the regulation are presented in appendix 4 of this report. At present, the Swedish Radiation Safety Authority is introducing changes in the regulation concerning clearance of materials in order to be in full agreement with the new basic safety standards, Directive 2013/59/Euratom.

SKB has issued a guidance report [35] on clearance during dismantling and demolition of nuclear power plants.

The tables in section 5.1 in this report indicates that at least 20 % of the total estimated amount of metal is not contaminated and can thus be immediately released. Out of the total amount of concrete (building materials) approximately 99 % can be released.

6 Unplanned Releases of Radioactive Effluents

6.1 Review of Accidents of Internal and External Origin which Could Result in Unplanned Releases of Radioactive Substances

The licensee of a nuclear facility must verify that the probability of serious disturbances or mishaps is low and that, should such an event nevertheless occur, the consequences to the environment and personnel are acceptable.
SSM regulation SSMFS 2008:1 [12] stipulates "*The safety analyses shall be based on a systematic inventory of events, event sequences and conditions which can lead to a radiological accident".* For decommissioning it further stipulates that *"The safety analysis for the decommissioning of a facility should particularly take into account factors such as rapid changes in facility status, the removal of both active and passive safety functions, the handling of large quantities of nuclear waste, as well as unusual and changing working conditions".*

When the two units reach Care and maintenance, it means that all the used nuclear fuel has been transported off site, the risk of major radioactive releases is thus minimized. Furthermore, there are no inherent driving mechanisms such as high temperatures, high pressure and the amount of oils and chemicals is reduced which reduces the risk of a fire that can release activity.

The methodology used to find the limiting events can be described in the following steps.

1. Mapping of rooms, systems and components that contains radioactive materials.
2. Mapping of events that may occur.
3. Identification of limiting events with regard to radioactive releases.
4. Identification of the relevant frequency for the identified events.

Sections 6.1.1 and 6.1.2 in this report describe in more detail the most relevant events. Information in references [36-40] has been used.

6.1.1 External events

The safety analysis report for a plant in power operation and normal outage contains information regarding external events. In this report information about geological and hydrological situation at the NPP is described in section 1. Some of the events are relevant also for the decommissioning, in the sense that the effect on buildings, are the same. However the analyses performed for power operation indicate that the effect on buildings is limited and that there are no consequences on the surrounding environment.

The following events are analysed or considered for normal (power) operation. Information if they still are relevant to consider for decommissioning is included. The results from the power operation analysis are considered to be relevant also for decommissioning. That is, if there are no radiological releases during power operation there is no consequence during decommissioning.

- Pollution in the sea cooling water (not relevant for decommissioning).
- Temperature of the sea cooling water (the units use deep water intake) (not relevant for decommissioning).
- Extreme water levels (both high and low).
  (relevant for decommissioning but no consequences).
- Extreme air temperatures, both high and low temperatures
  (not relevant for decommissioning).
- Air pollution, chemical or radioactive releases from another plant (not relevant for decommissioning due to limited need for plant monitoring).
- Extreme rain, snow or wind (relevant for decommissioning but no consequences).
- Tornado and generated missiles (relevant for decommissioning but no consequences).
- Airplane crash. For normal power operation this event is classified as an extreme low risk event and therefore not analysed further.
- Transport accidents (heavy vehicles hit buildings).
  (relevant for decommissioning but no consequences)
- Accidents in the hydrogen production building
  (relevant for decommissioning but no consequence).
- External fire (relevant for decommissioning but no consequences).
- Lightning (relevant for decommissioning but no consequences).

- Electromagnetic disturbances (not relevant for decommissioning).
- Sun storms (not relevant for decommissioning).
- External power disturbances (not relevant for decommissioning).
- Earthquake.
  In Scandinavia, seismic activity is generally low. Only a few incidents have been registered in historic time, which perhaps could have damaged an industrial plant today. The risk of a nuclear accident in Sweden caused by an earthquake may thus be considered as low. Over the years the demand on safety with respect to nuclear power has increased. It was therefore also necessary to evaluate the seismic safety. In order to find a common view of how to handle earthquake events, a joint project (the nuclear industry and the authority SSM) was initiated in the mid 1980s with the aim to find suitable conditions and requirements, for example seismic response spectra and probabilistic assessment of seismic ground motion characteristics. Earthquake as an analysis precondition special event (not a realistic event) is therefore analysed also for decommissioning.

6.1.2 Internal events

The following events are analysed or considered for power operation and are to some extent relevant also for decommissioning.

- Internal fire.
- Internal flooding. Internal flooding includes all types of water sources. In general, it is the most important consequence if the released water increases to such a level that components and/or the integrity of a room is affected.
- Load drop. Drop of heavy components that affect the integrity of a building or structure or hit components or systems that either release water or leave a system inoperable.
- Operator mistakes.

In order to find the most relevant events for decommissioning the above mentioned events are analysed further with the precondition that the units no longer contains any spent fuel and that there are no driving mechanisms such as high pressure or high temperatures.
The safety analyses for Oskarshamn 1 and 2 and the waste handling building (0AVF) have identified the following relevant limiting

accidents starting from Care and maintenance to be analysed further. The limiting accidents are:

- Fire in the carbon filters for the spent fuel pool cooling. This event is not realistic since the filters are wet but in order to find an event/component that for sure contains relatively high levels of radioactive substances this event was analysed. This case is hypothetical.
- Pipe break in the spent fuel pool cooling system.
- Pipe break in the system for drainage of active water.
- Load drop, RPV head or heavy reactor internals. This type of event is relevant during the period when the reactor internals are dismantled.
- Operator mistake during back flushing or changing of filter in the spent fuel pool cooling system.
- Fully developed fire in a fire cell with high radioactive classification in the waste handling building where the fire gases are ventilated to the atmosphere. This event is not realistic since the fire detection system and automatic fire fighting system will be in operation. But it is analysed to indicate an overestimated release level.
- Earthquake that causes the drainage tank or the storage/delay tank for active gases to crack. This case is a special event.
  Earthquake is a low probability event. In Sweden the bedrock is very stable and an earthquake that can affect a unit is unlikely but earthquake is a pre conditioned initiating event.
- Earthquake that affects the waste handling building followed by a fire that releases the entire radioactive content. This event is extremely overestimated and used in the analysis for normal power operation to obtain a worst case scenario.
- Malfunction in system for radioactive waste water that is not identified and no action taken until after 8 hours.

The above listed accidents are also applicable during dismantling, as long as there is water in the pools. In order to reduce the risk of leakage the plan is to eliminate the water as soon as possible, this is, when all the radioactive material in the spent fuel pools have been packed and transported to their chosen destination. That leaves events with flooding with clean water that can affect the integrity of a building.

A study of occurrences during segmentation of the internal parts of the reactor, where six occurrences have been identified [36-37], the segmentation is performed under water so only small quantities of airborne releases are expected during the process.

Four of the identified possible occurrences are operator mistakes, such as:

- Movements of core internals with poor water cover.
- Drop of radioactive chips or particles over the reactor hall floor.
- Occurrence during handling of portable filter.
- Occurrence with equipment for drying the core internals. This occurrence can also be caused by equipment errors.

The other two identified occurrences are drop of loads above 1,000 kg, such as:

- Drop of a tank with segmented reactor internals on the reactor hall floor.
- Drop of a filled steel or concrete tank in the lift shaft.

During the main part of the dismantling process, the handling of radioactive components, cutting, lifting and transporting will be sources of accident risks together with the risks that are valid throughout the dismantling process, for example fire and accidents in the waste handling systems (handling of filters and water spill).

It is assessed that the above mentioned and analysed unplanned events are the most relevant to analyse during dismantling and demolition, and that the outcome regarding releases (discussed in section 6.3) covers other unplanned events.

6.1.3 Risks during interim storage

In the safety analysis report for BFA some potential accidents are analysed.

- Malfunction in the electrical power system.
- Malfunction in the drainage system.
- Disturbances when transporting and handling/lifting radioactive material (containers/tanks).

None of the identified events are analysed further with respect to radioactive releases. During interim storage in BFA of steel/concrete tanks containing segmented reactor internals no handling of the containers are expected. Thus, there are no unplanned releases of radioactive substances due to handling of the containers during the remaining period before transport to the final repository. No new internal or external events are identified. During interim storage of other types of contaminated or activated components or material there is no additional handling of the containers/tanks planned before transport to SFR.

6.1.4 Overestimated approach in order to identify worst case scenario

Looking at the activity content it can be assumed that the segmentation of internal parts and the following packaging and transportation is one of the worst case scenarios together with fire in filters with high activity content.

Earthquake is another worst case scenario, when it is combined with non-realistic assumptions such as fire.

No flooding event has been identified as limiting since there is no flooding event that affects the integrity of a building and no water release has been identified outside any building.

6.2 Reference Accident(s) Taken into Consideration by the Competent National Authorities for Evaluating Possible Radiological Consequences in the case of Unplanned Releases

The Swedish authorities have not considered any accidents during decommissioning, since this is the responsibility of the operator of the NPP.

According to chapter 6.1 the following cases were identified as potentially generating external releases in the event of an accident.

6.2.1 External events

The results from the analysis performed for power operation indicate that there are no consequences for the environment for any of the events. The events are therefore not further discussed, except earthquake.

Earthquake that causes a tank for radioactive gases to crack

Earthquake is not a realistic event but Swedish NPPs must perform earthquake studies. The earthquake is combined with radioactive release from a cracked tank that contains radioactive substances.

6.2.2 Internal events

Fire

In order to find a worst case scenario, it is assumed that a fire in highly radioactive filters can occur.

Segmentation of internal parts

During the process of segmenting the internal parts, the highest risk that can cause a release to the environment is a load drop and occurrence with the equipment for drying the core internals.

Flooding

No flooding event is analysed further.

6.2.3 Interim storage in BFA

No events are analysed further.

6.3 Evaluation of the Radiological Consequences of the Reference Accident(s)

6.3.1 Accidents entailing releases to atmosphere

The results from the analyses are summarized below and details can be found in [41-45]. A method for calculating dispersion and doses has been developed in a joint project between the nuclear industry and the authority, SSM, and the result can be found in *Methodology Handbook for Realistic Analysis of Radiological Consequences* [50]. The handbook describes a methodology for analysing the radiological consequences of releases of radioactive substances (shortened to "radioactive releases") from accident events, is given hereinafter.

The handbook presents methods, data and parameters for a best-estimate (BE) analysis of the radioactive releases. The use of the handbook is based on the assumption that where appropriate, a transient analysis has already been performed that describes the sequence of the event and results in a radioactive release.

The handbook provides information to analyse the radiological consequences at distances from 0 m to 30 km from the plant. The handbook provides a general description and justification of the parameters, and assumptions in the transient analyses can be used as best-estimate values. The handbook presents the methodology and parameter values for realistic calculations of radiological consequences for all events that are analysed for conservative radiological consequences in the current safety analysis report (SAR). The handbook does not dictate the events that the nuclear power plants shall analyse and present with respect to realistic evaluations of radiological consequences.

Another purpose of the methodology presented in the handbook is to differentiate the realistic case from the conservative radiological consequence analyses. Whenever it is possible, actual knowledge of the plant and event shall be applied.

The handbook includes the following sections:

1. ***Introduction*** – information on background and scope of the handbook
2. ***Method*** – description of strategy
3. ***Source terms*** – description of chemistry and activity as applied in the calculations, as well as other factors that affect nuclide release
4. ***Accident sequences*** – calculation methods and input data for analysis of each event. This is where the specific parameters and methods for analysing the various accidents are covered.
5. ***Calculation of doses from radioactive releases***
6. ***Acceptance criteria*** – discussion of reference values
7. ***Uncertainty*** – generic method for estimating uncertainty in the calculations.

In the handbook, the dispersion and dose model LENA2003 is used. The model is developed by SSM and described in the handbook. The LENA model is used for the calculations presented in this report.

Assumptions used

Pasquill	F	D	
Windspeed		2 m/s	3 m/s
Elevation for mixture	100 m	150 m	

Deposition velocity inorganic iodide		0.02 m/s
Deposition velocity organic iodide	0.0002 m/s	
Deposition velocity particles	0.002 m/s	
Time frame for release		1 hour
Integrated time	720 hours after release	

Event	Effective dose (mSv) 0-500 m	Effective dose (mSv) 500 m - 15 km	Thyroid gland dose (mSv) 500m – 15 km
Earthquake that causes the drainage tank or the storage/delay tank for active gases to crack (O1) ref [42]	6.6E-2	2.0E-2	2.4E-3
Fire in activated filters (O1) ref [42]	2.8E-7	2.0E-6	1.8E-7
Earthquake that causes the storage / delay tank for active gases to crack (O2) ref [43]	9.8E-2	6.8E-2	3.4E-3
Fire in activated filters (O2) ref [43]	1.4E-6	5.6E-5	3.2E-6
Fully developed fire in a fire cell with high radioactive classification where the fire gases are ventilated to the atmosphere. Ref [45]	5.9E-4	4.1E-4	7.8E-6
Drop of filled steel tank in the lift shaft (O1) ref [41]*		1.7E-6	
Occurrence with equipment for drying the core internals. (O1) ref [41]		1.7E-6	
Occurrence with equipment for	8.6E-7	6.4E-5	9.3E-7

drying the core internals. (O2) ref [44]			
Earthquake in combination with fire in the waste management building	4.6E-4	1.6E-4	6.1E-3

**This accident is not relevant for Oskarshamn 2. The event is conservatively included for Oskarshamn 1.*

The radiological consequences of the accidents stated in section 6.1 have been analysed and found to be without harm to the environment.

There is always a risk during the handling of material in the reactor hall pools, but this will primarily affect personnel in the reactor hall. During movement and lifting objects out of the pools there is a risk that the wrong object is picked up, or that an object is lifted too high. Measurement of dose rates on all components and a well-structured system that keeps track of where each component is minimizes the risk for handling accidents of this type.

Systems already existing for ventilation and monitoring of radioactivity are used in the plant and contribute to limiting and controlling potential releases. During the dismantling process, ventilation and monitoring system must, however, be adopted according to the actual situations and temporarily installations can be used. In summary it can be stated that the plant easily meets the requirements that apply from a radiological perspective concerning the radiological effects on the environment and plant personnel associated with disturbances and mishaps when handling reactor internals.

All the above identified and calculated events are well below the acceptance level for releases to other member states. Additionally, OKG does not expect any food exports from the vicinity of Simpevarp, see section 1.4

6.3.2 Accidents entailing releases into an aquatic environment

No accident has been identified that could give a release to the aquatic environment during the decommissioning period that could effect the surrounding member states.

7 Emergency Plans, Agreements with other Member States

As mentioned in the introduction to this report, the nuclear fuel will be transferred off-site to the interim storage Clab (see appendix 3) before any dismantling activities can be performed.

The operator of the Oskarshamn NPP has a plan for emergency preparedness [46] in the event of an emergency or a threat of an emergency at the facility. Since Oskarshamn 3 will continue to operate there will be no major changes in the emergency preparedness plan. The plan describes the whole scope of the emergency preparedness at OKG including reference to relevant documentation regarding radiation protection measures. Relevant documentation including checklists for all functions in the emergency preparedness organisation is collected in a handbook that is available for the Emergency Preparedness Management. The handbook is well known and training is performed regularly.

The current plan describes the organisation, including available personnel with competence in relevant areas, such as Emergency Preparedness Management (Crisis Management Team, CMT), Engineer on Duty (EOD), Area Supervisor (Crisis Manager, CM), Plant Supervisor O1, Plant Supervisor O2, Plant Supervisor O3, Radiation Protection Supervisor, Service Supervisor and Information Supervisor

Alarm levels, instructions and routines to activate the alarm, instructions for informing relevant authorities and evacuation plans are described. Equipment and technical facilities for radiation measurements and contamination control are available and their use is regularly exercised. Meteorological data is measured and registered continuously.

According to the Swedish Regulation on Civil Protection [47] the County Administrative Board of the County of Kalmar has established an emergency plan [48] where the Oskarshamn NPP is included. The plan covers organisation, liaison with other authorities and the operator, where and how to measure radioactivity, how to handle public information, personnel and material resources available in the county, and methods of decontamination.

Sweden has signed international and bilateral agreements on a national and official level concerning the early notification and subsequent information in the event of a nuclear energy accident. The Swedish Meteorological and Hydrological Institute (SMHI), which is manned around the clock, receives notifications of accidents abroad. The Swedish Radiation Safety Authority SSM, which is manned around the clock, is responsible for forwarding the information nationally, and also for sending information from Sweden in the event of an accident in the country. The most important agreements are:

- Bilateral national agreements with Norway, Denmark, Finland, Germany, Russia, and Ukraine on warnings of accidents.
- The IAEA convention EMERCON on warnings of accidents if another country might be affected by release.
- The binding EU directive on early notification (ECURIE, European Community Urgent Radiological Information Exchange) requires that a warning must be given if measures are adopted for protection of the domestic population.

8 Environmental Monitoring

8.1 General Description

The purpose of the radiological environmental monitoring programme is to examine the impact on the environment on account of the operation of nuclear power plants as well as activities related to dismantling and demolition. At Simpevarp, the activities at the interim storage for spent fuel (Clab) are also included in the programme since OKG and Clab are both located at the Simpevarp peninsula. The levels of radionuclides in the vicinity of the nuclear power plants are monitored, as a complement to measurements of the discharges to air and water. The monitoring programme also detects larger unregistered discharges. Long term monitoring of radionuclides in the environment produces basic data enabling estimation of potential effects on biological life in the recipient. The results can be used for informing the public and as a basis for international reporting and other collaboration in the environmental area.

The Swedish Radiation Safety Authority (SSM) requires nuclear facilities to monitor the environment in accordance with a programme specified by SSM in the regulation on Protection of Human Health and the Environment in connection with Discharges of Radioactive Substances from certain Nuclear Facilities, SSMFS 2008:23 Section 20. At present the SSI (the former Swedish Radiation Protection Authority) report 2004:15 [51] describes the content of the environmental monitoring programme for the four nuclear power plants in Sweden, as well as nuclear activities in Studsvik and the fuel fabrication facility in Västerås. The main focus is on biota, but also water, atmospheric precipitation, digested sludge and sediments are included. The report was revised in 2005.

SSI 2004:15 defines selection of samples and their locations, preparation, analyses, evaluation and reporting. The samples include e.g. moss, apples, seabed sediment, close-by manufactured milk, fish and meat, and the samples are analysed by nuclide specific gamma spectroscopy using High Purity Germanium detectors (HPGe). The main radionuclides are Cs-137 and Co-60 as well as naturally occurring radionuclides, mainly K-40. The activity levels and the detection limits of specified radionuclides are reported to SSM. Sampling is performed by the Swedish University of Agricultural Sciences (SLU). Sample preparation and analyses are performed at the OKG environmental laboratory in unit O3, in accordance with the guidelines developed by SSM for environmental monitoring. Meteorological data are continuously recorded, see section 1.3 for further information.

The monitoring programme consists of two different parts: one annual and one extended investigation every fourth year. The annual programme makes it possible to detect changes in the environment in the short-time interval and to detect trends on a longer time-scale. The extended investigations give more correct long-term results and also cover a wider geographic area. The sampling locations are shown in figure 8-1.

Figure 8-1. Sampling stations in the vicinity of Simpevarp in the environmental monitoring programme, both on land and in water [51].

There are 25 area dosimeters that are evaluated on a quarterly basis, see further description in section 8.3. As a supplement, there are nine dose rate meters that are checked twice a week for trend analyses. The dose rate meters can also be used during accident conditions for estimation of source term and for calculation of dose to the surroundings.

To ensure the quality of the measurements, inter-calibrations are performed on an annual basis for radiochemical analyses at OKG, together with other nuclear power plants in Sweden and Finland as well as other organisations involved in radiochemistry. Audits and follow-up of sampling and results are also performed by SSM.

The nuclear power plant operators in Sweden held a meeting with SSM in June 2016 regarding new regulations for environmental monitoring and the work is currently in progress. The operators will take more responsibility when it comes to the content of the environmental monitoring program in the future.

The monitoring program will continue as long as OKG and SKB/Clab handle radioactive material at Simpevarp, i.e. irrespectively of the demolition of Oskarshamn 1 and 2.

8.2 Historical Radiological Effect from Power Production

Generally, the operations at OKG do not affect the environment in a radiological perspective, since the releases of radioactive substances to air and water are well below the specified limits. The effective dose to any individual in the reference group from discharges to water and air from all facilities situated within the same geographical area shall not exceed 0.1 mSv per year according to the regulation SSMFS 2008:23 section 5.

The Chernobyl accident has caused increased levels of Cs-137 in all environmental samples. In the seabed sediments in Hamnefjärden (see figures 8-4, 8-5 and 8-6) where the water discharges are released, increased levels of radioactivity from the operation of the nuclear reactors are found, e.g. Co-60.

The maximum calculated doses to the reference group during 1985 to 2016 are shown in figure 8-2. Children 7-12 years have historically received the highest dose in the reference group and are thus used in the diagrams below that illustrate dose from water and air discharges during power operation. The same dose factors as those described in section 3 and 4 of this report have been used in the calculations.

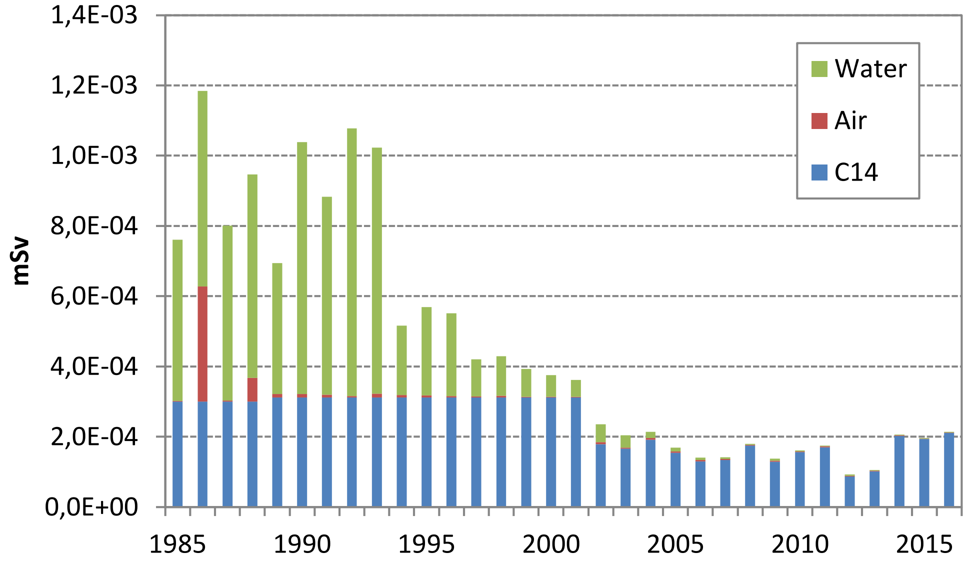

Figure 8-2. Effective dose to children age 7-12 years in the reference group from discharges to air and water from OKG/Clab during 1985-2016.

C-14 is the most important nuclide during power operation. Before 2002 the dose contribution from C-14 was calculated based on the installed thermal power for the different reactors.

Oskarshamn 1 suffered fuel damages before 1980 where approximately 200 g UO_2 were released [49]. In 1988 extensive fuel damages occurred in both Oskarshamn 2 and Oskarshamn 3, with releases of 450 g and 130 g respectively of UO_2 to the core. The decrease in air releases during the following years can be explained by fuel replacements. Additionally, in 1997 and 2000 fuel damages explain the increased releases to air.

The 18 fuel damages in Unit O3 during the last couple of years (2004-) have not significantly increased the doses to the reference group due to a more strict policy on operation with fuel damages.

In the following figures activity contents in fish (figure 8-3), sediment (figures 8-4 and 8-5) and moss (figure 8-6) during power production are illustrated. The positions for the sampling stations are given in figure 8-1.

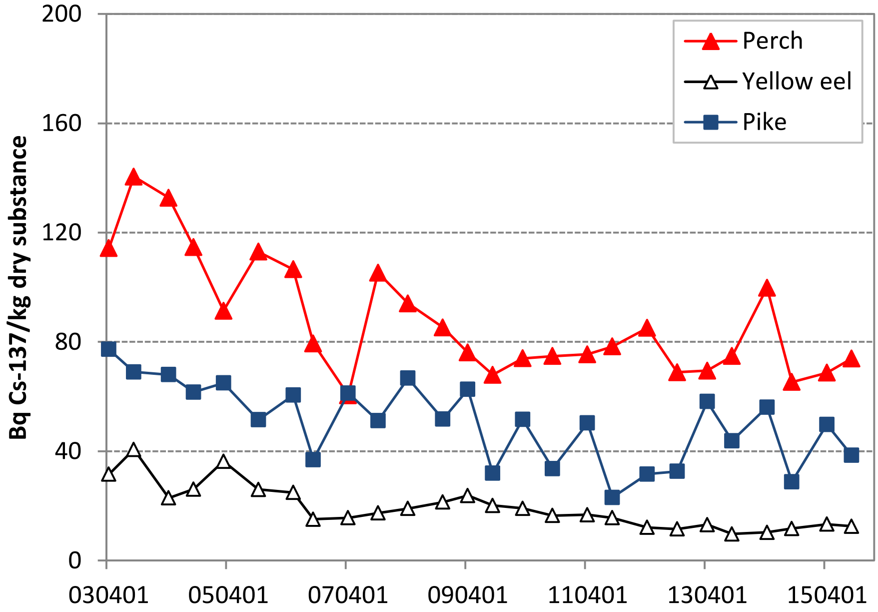

Figure 8-3. Activity levels of Cs-137 in three different types of fish, sampling station 1 according to figure 8-1.

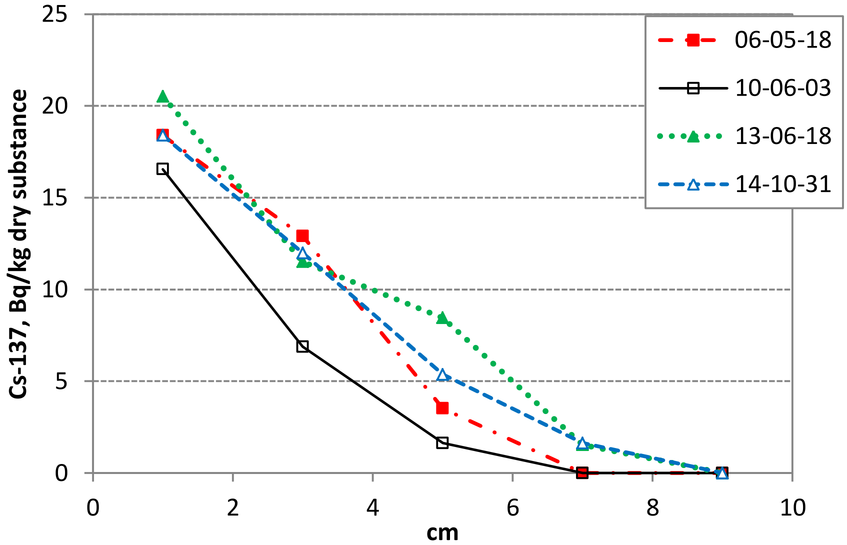

Figure 8-4. Activity levels of Cs-137 in sediment, sampling station 36 according to figure 8-1 (HELCOM).

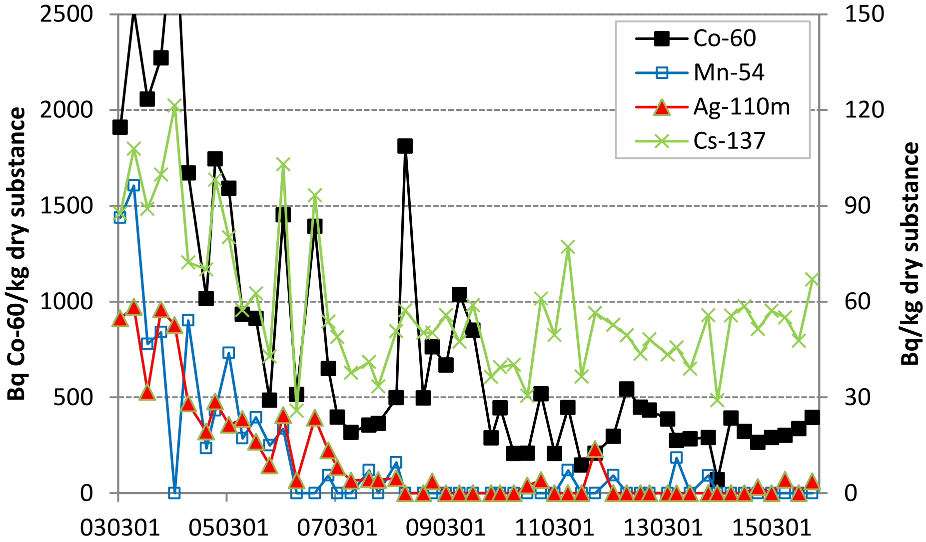

Figure 8-5. Activity levels of Co-60, Mn-54, Ag-110m and Cs-137 in surface sediments,0-2 cm, sampling station 2 according to figure 8-1 (Hamnefjärden).

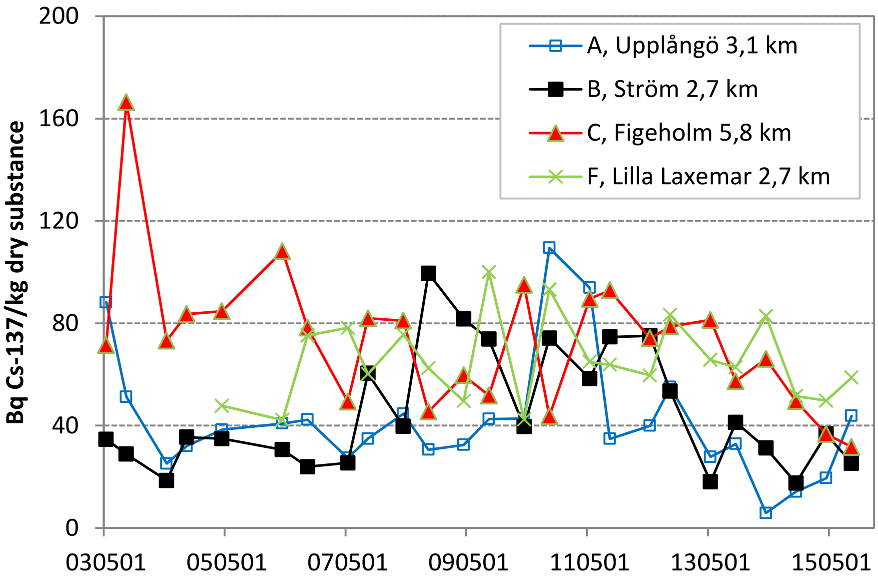

Figure 8-6. Activity levels of Cs-137 in moss, sampling stations A, B, C and F according to figure 8-1.

The activity contents in various sample types are low. The most common nuclide is Cs-137 (half-life 30.2 years) that mainly comes from the Chernobyl accident in 1986.

According to the expected discharges to air and water described in sections 3 and 4 of this report, the levels in the environment will continue to be on a constant level, or decreasing. The most affected samples are the sediments outside the water discharge outlet in Hamnefjärden, where nuclides such as Co-60, Mn-54 and Ag-110m that are produced during power operation are found. The production of these nuclides will cease when the nuclear power production is stopped. During decommissioning the discharges will possibly continue as long as the facilities contain radioactive material. The total activity inventory of the nuclear reactors will also be affected by the half-lives of the nuclides and thus after a couple of years only the more long-lived nuclides will remain.

8.3 Dose and Dose Rate Measurements

On the Simpevarp peninsula there are 25 area thermoluminescent dosimeters (TLD) that are used to measure beta and gamma radiation. The dosimeters are placed on various distances from the nuclear power plant, see figure 8-7 and table 8-1.

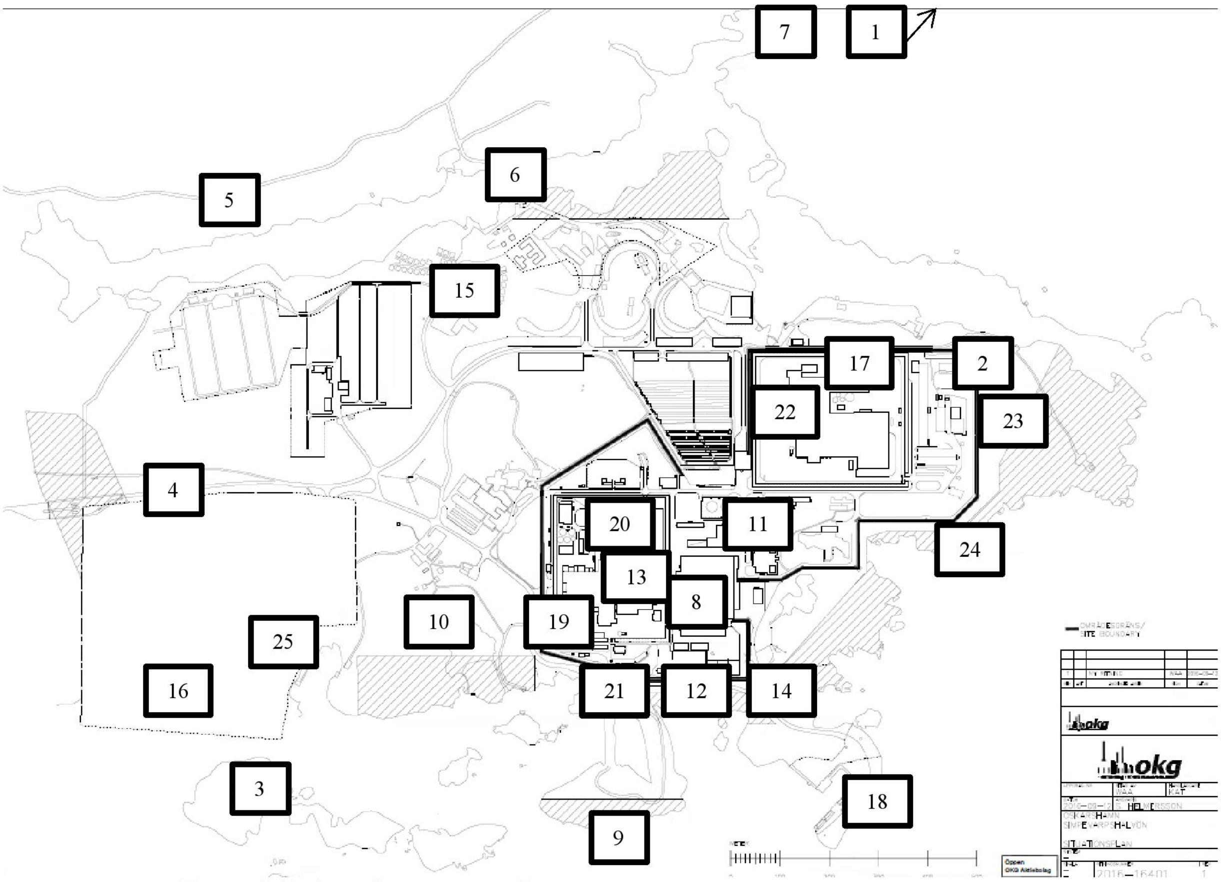

Figure 8-7. Area dosimeters at Simpevarp.

Some of the dosimeters (positions 1, 2, 3, 4, 5, 6, 7, 9, 18) fulfil the SSMFS 2008:23 section 22 requirement to continuously monitor gamma radiation in the vicinity of OKG.

Table 8-1. Area dosimeter descriptions.

Position	Description	Position	Description
1	Ävrö area	13	Close to O1/O2
2	Hamnefjärden	14	Central workshop (South East)
3	Screening plant, Clab	15	Sörå village
4	Road crossing	16	Clab
5	Water reservoir	17	Sewage plant
6	Embankment	18	Harbour
7	Båstadsfjärden Naturvårsverket	19	West fence O1/O2
8	Central workshop (North West)	20	North fence O1/O2
9	Pier Tallskär	21	South fence O1/O2
10	Old village	22	West fence O3
11	Main entrance and access control building	23	East fence O3
12	Gate to O1/O2	24	East gate O3
		25	East gate Clab

The results from dose evaluation from 1985 to 2016 are shown in figure 8-8 (Position 4, road crossing, see figure 8-7).

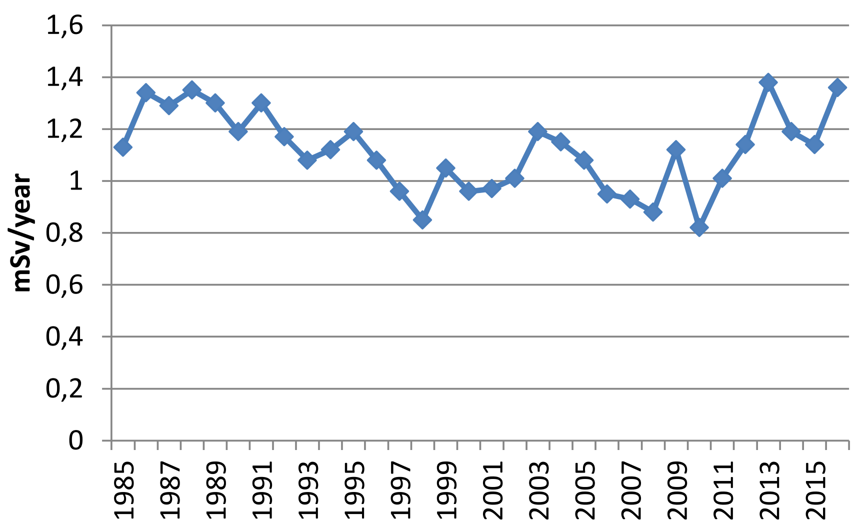

Figure 8-8. Background levels measured by area dosimeter in Position 4 (see figure 8-7), road crossing.

The background levels are more than a factor 1,000 higher than the dose received in the reference group from the power production at OKG (see figure 8-2). The dose contribution from the power production is thus negligible compared to the natural background.

On site there are also nine dose rate meters in the so called Skylink system that continuously measure the dose rate at various location close on the Simpevarp peninsula. Two units are mobile and can be placed where needed. The instruments consist of two Geiger-Müller (GM) tubes and are designed to be able to measure low dose rates (>20 nSv/h) at normal operation as well as elevated dose rates (<10 mSv/h) at accident conditions. The measurements are checked twice a week as part of the normal routines in the emergency preparedness organisation.

SSM also has a regional measuring system that consists of permanent measuring stations around nuclear power plants that will be in operation from the beginning of 2017. The system consists of 20 measuring stations (GM-tubes) at 5 km distance and 10 stations at 10 km distance from OKG. The purpose of this system is to detect and follow-up large emissions during accident or a large failure conditions.

8.4 Environmental Surveillance Analyses

The surveillance programme is in general divided in two sampling periods; spring (1 April to 1 June, generally prior to the outages) and autumn sampling (1 September to 31 October, after the outages). The samples for the extended investigation performed every fourth year are collected in the spring period.

Table 8-2. Sampling on land, the letters refer to positions in figure 8-1.

	Sampling	
Natural vegetation	**Spring**	**Autumn**
Haircap moss	A-C,F	A-C,F
Reindeer lichen		A- C, F
Spruce sprout		C, F
Cultured vegetation		
Lettuce (in July)		B
Pasture		A, B
Threshed grain		B
Fruit (apple)		B
Berries (redcurrant)		B
Animal samples		
Cattle (beef)		B
Milk (every second week)	G	G
Sludge, sewage plant		
Ankarsrum		X
Figeholm		X
Kristdala		X

In recent years there have been problems with access to cattle and threshed grain since there are no farms with these kinds of production nearby anymore. The sludge from Kristdala has been sent to Oskarshamn because the station is normally unmanned. Milk is analysed every other week when the cows are outside.

Table 8-3. Sampling in water, the numbers refer to positions in figure 8-1.

	Sampling	
	Spring	**Autumn**
Sediment		2, 36
Algae		
Biofouling samples (once a month)	24,25	24,25
Bladderwrack		11,12,15,17, 18,19,23
Molluscs		
Theodoxus		6
Common sea mussel		12,15,17
Baltic sea clam		20
Fish		
Yellow eel	1,17,18	1,17,18
Baltic flounder	7	7
Baltic herring		7
Pike	1	1
Perch	1,17,18	1,17,18

There are alternative species for some of the sample types in case it is difficult to catch specimens with the correct size in the specified position.

Table 8-4. Sampling in extended investigation, the numbers refer to positions in figure 8-1.

	Spring
Algae	
Green algae (Cladophora glomerata)	6,12
Bladderwrack	11,12,15,17,18,19,23 ,52
Molluscs	
Theodoxus	6,12,18
Common sea mussel	11,12,15,17
Baltic sea clam	20
Sediment	36,37,38,39,40,41,45 , 46,47,48,49,50,51

Sediment samples are taken at different depths at position 36, see figure 8-4.

9 References

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(*Unit 0, 1, 2, and 3 – Mapping of Events with Importance for Decommissioning*)

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11 MSBFS 2016:8 - Myndigheten för samhällsskydd och beredskaps föreskrifter om transport av farligt gods på väg och i terräng (ADR-S)
(*The Swedish Civil Contingencies Agency's Regulations on Transport of Dangerous goods by Road*)

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(*Report on Releases of Radioactive Substances*)

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30 Report – Studsvik/ES-01/37 – Dosomräkningsfaktorer för normalutsläpp. E. Områdesbeskrivningar och kritisk grupp (*Dose Conversion Factors for Normal Releases. E. Site Descriptions and the Critical Group*)

31 Report – Studsvik/ES-01/38 – Dosomräkningsfaktorer för normalutsläpp. F. Metodrapport (*Dose Conversion Factors for Normal Releases Methodology Report*)

32 Directive 96/29/Euratom - Ionizing radiation of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation, 96/29/Euratom

33 SSMFS 2011:2 - The Swedish Radiation Safety Authority's regulations and general advice concerning clearance of materials, rooms, buildings and land in practices involving ionising radiation,

34 SKB-report R-13-04 - Decommissioning Study of Oskarshamn NPP

35 SKB R-16-13 - Friklassning vid nedmontering och rivning av kärntekniska anläggningar (*Clearance during Dismantling and Demolition of Nuclear Power Plants*)

36 2016-09396 ed. 1 - Oskarshamn 2 – Identifiering av händelser i samband med partiell nedmontering, (*Identification of Potential Events during Partial Dismantling*)

37 2015-02510 ed. 1 Oskarshamn 1 ProAct – Identifiering av händelser i samband med partiell nedmontering, (*Identification of Events During Partial Dismantling*)

38 2014-25620 ed. 1 - Oskarshamn 1 – Projekt ProAct – Referens till O1 Servicedrift SAR A1 kapitel 6 – Identifiering av händelser som ska analyseras (*Identification of Events that are Relevant to Analyse during Care and Maintanence*)

39 2016-05136 ed. 1 - Oskarshamn 2 - Servicedrift - Identifiering av händelser som ska analyseras (*Identification of Events that are Relevant to Analyse During Care and Maintanence*)

40 2016-08656 ed. 1 - 0AFV - Referens till Servicedrift SAR A1 kapitel 6 - Identifiering av händelser som ska analyseras (*Identification of Events that are Relevant to Analyse, in the Waste Handling Buildning*)

41 2015-04088 ed. 1 - Oskarshamn 1 – ProAct - Radiologisk konsekvensanalys av händelser I samband med partiell nedmontering (*Radiological Consequence Analysis During Partial Dismantling*)

42 2015-01539 ed. 1 - Oskarshamn 1 – Servicedrift – Referensrapport - Individdoskonsekvens vid händelser (*Dose Consequence for Individuals at Identified Events*)

43 2016-08580 ed. 1 - Oskarshamn 2 - Servicedrift - Referensrapport - Individdoskonsekvens vid händelser (*Dose Consequence for Individuals at Identified Events*)

44 2016-21267 ed. 1 - Oskarshamn 2 - Beräkning av dos till omgivningen i samband med partiell nedmontering (*Dose Calculations to the Environment during Partial Dismantling*)

45 2016-14516 ed. 1 - 0AVF - Referensrapport - Individdoskonsekvens vid händelser (*Dose Consequence for Individuals at Identified Events in the Waste Handling Building*)

46 2005-10452 - Beredskapsplan, OKG plan (*Emergency Plan*)

47 SFS 2003:789 - Förordning (2003:789) om skydd mot olyckor (*Ordinance on Protection against Accidents*)

48 Beredskapsprogram 2011-2012 för räddningstjänst och sanering vid kärnteknisk olycka i Kalmar län, dnr 452-6177-10 (*Contingency Programme for Rescue Services and Clean-Up at a Nuclear Accident in the County of Kalmar*)

49 2005-06501 ed. 4 - Oskarshamnsverket - Generell handlingsplan för att förhindra och hantera bränsleskador (*General Action Plan to Prevent and Handle Fuel Damages*)

50 Methodology Handbook for Realistic Analysis of Radiological Consequences T-NA10-24

51 SSI 2004:15 - Omgivningskontrollprogram för de kärntekniska anläggningar revision (*Environmental Surveillance Programme for Nuclear Power Plants, revised*)

Appendix 1 – Definitions and terms used in this document

0AVF	The shared waste handling building for Oskarshamn 1 and 2
Acceptance criteria	Conditions to verify that a requirement is met
BAT	Best Available Technique
BE	Best Estimate
BFA	The bedrock depository for active waste
BWR	Boiling water reactor
CAB	County Administrative Board
Care and maintenance period	Commences when all nuclear fuel has been transported from the facility. The Care and maintenance period prevails until the Dismantling and demolition commences. Planning for the Dismantling and demolition is included in the planning for Care and maintenance period
Clab	Central interim storage for spent fuel
CSV	Central workshops
Dose factor	Conversion factor (mSv/Bq) that is reactor specific and used to calculate dose from discharged activity (Bq)
ECURIE	European Community Urgent Radiological Information Exchange
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
HLA	Low level waste handling building
HPGe	High Purity Germanium Detector
ILW	Intermediate level waste
LLA	Interim storage building for low level waste at OKG
LLW	Low Level Waste
MET	Meteorological mast situated at Simpevarp
MLA	Landfill on site
NPP	Nuclear Power Plant
O1	Oskarshamn 1
O2	Oskarshamn 2
O3	Oskarshamn 3
OKG	Oskarshamns KraftGrupp (the utility)
Reference group	Representative (real or hypothetical) group of people from the population that is expected to receive the highest radiation dose from the Simpevarp peninsula.
RPV	Reactor Pressure Vessel

SAR	Safety Analysis Report
SFR	Final repository for short-lived radioactive waste
SFS	Swedish Code of Statutes
SFL	Final repository for long-lived radioactive waste
SKB	Swedish Nuclear Fuel and Waste Management Company
SLU	Swedish University of Agricultural Sciences
SMHI	Swedish Meteorological and Hydrological Institute
SSM	Swedish Radiation Safety Authority
SSMFS	Swedish Radiation Safety Authority regulations
TLD	Thermoluminescent dosimeter
WAC	Waste Acceptance Critera
WGS84	World Geodetic System 1984
WLD	Waste Led Decommissioning

Appendix 2 – Doses from discharges of Co-60 to air and water from Oskarshamn 1 and 2

Table App 2-1. Doses in mSv/year from Co-60 discharges to air from Oskarshamn 1 and 2 for infants 1-2 years, children 7-12 years and adults.

Year	Infants	Children	Adults
2014	5.41E-07	5.48E-07	4.80E-07
2015	3.09E-07	3.13E-07	2.74E-07
2016	3.20E-07	3.24E-07	2.84E-07
2017	3.90E-07	3.95E-07	3.46E-07
2018	2.82E-06	2.86E-06	2.51E-06
2019	5.04E-06	5.11E-06	4.47E-06
2020	2.65E-07	2.68E-07	2.35E-07
2021	2.35E-07	2.38E-07	2.08E-07
2022	2.03E-07	2.06E-07	1.80E-07
2023	1.77E-07	1.79E-07	1.57E-07
2024	1.55E-07	1.57E-07	1.38E-07
2025	9.87E-08	1.00E-07	8.75E-08
2026	0.00E+00	0.00E+00	0.00E+00

Table App 2-2. Doses in mSv/year from Co-60 discharges to water from Oskarshamn 1 and 2 for infants 1-2 years, children 7-12 years and adults.

Year	Infants	Children	Adults
2014	1.01E-06	8.26E-07	2.58E-07
2015	1.02E-06	8.29E-07	2.59E-07
2016	5.63E-07	4.59E-07	1.44E-07
2017	8.64E-07	7.04E-07	2.20E-07
2018	7.57E-07	6.18E-07	1.93E-07
2019	6.64E-07	5.42E-07	1.69E-07
2020	5.82E-07	4.75E-07	1.49E-07
2021	5.11E-07	4.16E-07	1.30E-07
2022	4.48E-07	3.65E-07	1.14E-07
2023	3.92E-07	3.20E-07	1.00E-07
2024	3.44E-07	2.81E-07	8.78E-08
2025	3.02E-07	2.46E-07	7.70E-08
2026	2.64E-07	2.16E-07	6.75E-08

Appendix 3 – The Swedish system for the disposal of spent fuel and nuclear waste

A law was enacted in Sweden in the 1970s stipulating that anyone who used nuclear power to produce electricity must also manage and dispose of the waste. The nuclear power companies in Sweden therefore jointly established the Swedish Nuclear Fuel and Waste Management Company, SKB, with the assignment to manage and dispose of all radioactive waste from Swedish nuclear power plants.

Figure App 3-1 below shows the Swedish system for radioactive waste disposal.

The system for dealing with Swedish radioactive waste comprises a number of facilities that together provide a safe chain. The first links in this chain were already in place in the early 1980s, others still have to be constructed. The radioactivity level of the waste determines how it is managed. Radioactive waste not only from nuclear power plants but also radioactive waste produced in hospitals and industry must be safely disposed.

Transport by sea

Waste from nuclear power stations is transported by SKB's specially built vessel M/S Sigrid.

Central Interim Storage Facility for Spent .uclear Fuel (Clab)

Today all of the spent nuclear fuel produced by Swedish nuclear power stations so far, is in interim storage in Clab outside Oskarshamn. It is placed in storage pools located in rock vaults 25–30 meters underground and is under constant surveillance and control. Clab has been operating since 1985.

Clab is not a final repository but after interim storage, the waste will be moved to the Spent Fuel Repository that SKB plans to construct at Forsmark.

Final Repository for Short-lived Radioactive Waste (SFR)

This is where operational waste from nuclear power plants, which includes used protective clothing, replaced components and filtering materials that have been used to decontaminate reactor water, is deposited. Radioactive waste from hospitals, industry and research is also kept here. The repository is located at Forsmark in bedrock about 50 meters below sea level.

A license application has been submitted to the authorities in order to extend SFR, primarily to make room for decommissioning waste.

Encapsulation plant at Oskarshamn

After interim storage the spent nuclear fuel will be sealed into canisters and SKB plans to construct an encapsulation plant at Oskarshamn, together with Clab. The canisters will be made of copper with inserts of nodular cast iron. The facility is currently on the licensing process and it is planned to start operations around 2030.

Final Repository for Spent Nuclear Fuel at Forsmark

The planned Spent Fuel Repository forms the last link in the chain when it comes to dealing with spent nuclear fuel. The planned method consists in depositing the spent fuel in sealed copper canisters placed in rock vaults and surrounded by bentonite clay at a depth of 500 meters in the rock. The facility is currently on the licensing process and it is planned to start operations around 2030.

Final Repository for Long-lived Radioactive Waste (SFL)

SKB is also planning a final repository for long-lived and intermediate level radioactive waste, SFL. The facility is planned to start operations around 2045.

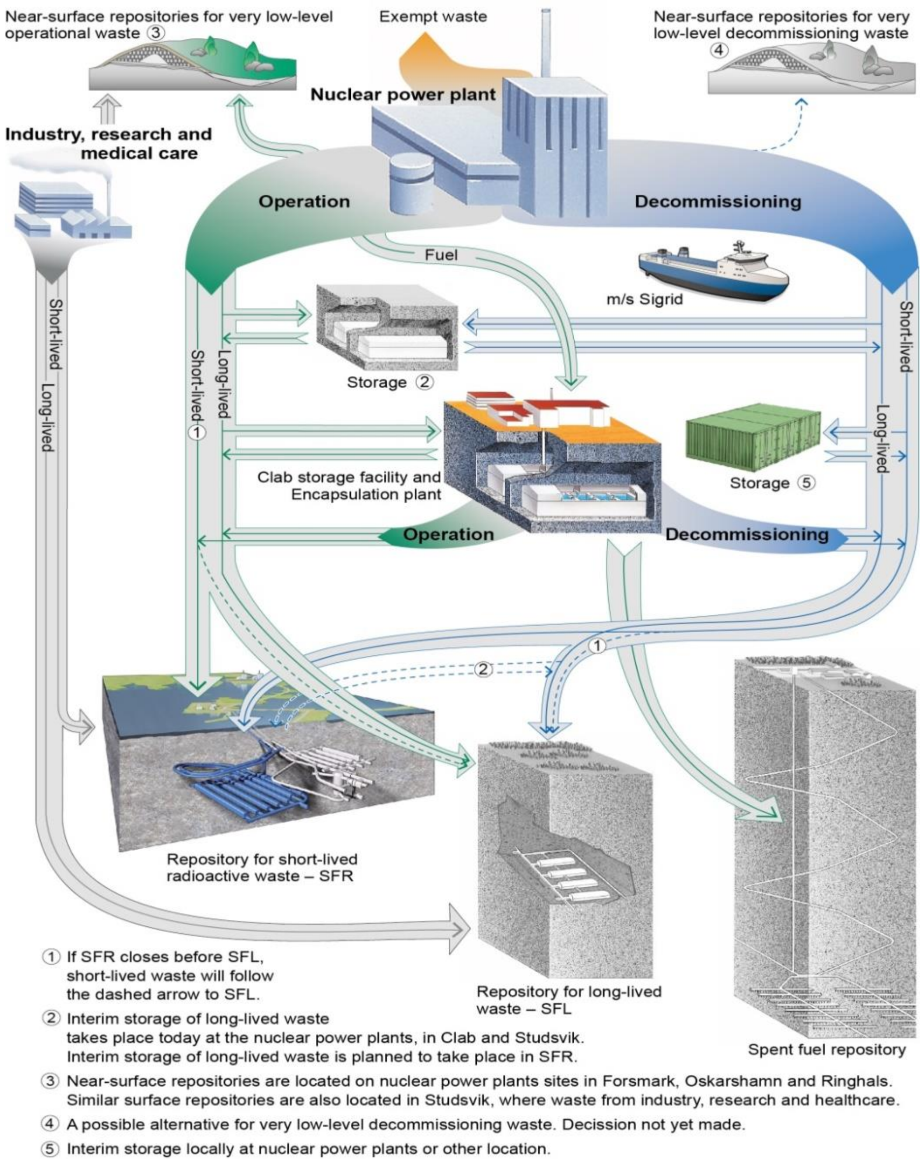

Figure App 3-1. The Swedish system for radioactive waste management.

Appendix 4 – Appendixes 1 and 4 in the Swedish Radiation Safety Authority's regulations concerning clearance of materials, rooms, buildings and land in practices involving ionising radiation (SSMFS 2011:2)

Appendix 1 ***Clearance levels for materials***

Nuclide	Clearance level (Bq/g)
H-3	100
Be-7	10
C-14	10
Na-22	0.1
P-32	100
P-33	100
S-35	100
Cl-36	1
K-40	1
Ca-45	100
Ca-47	1
Sc-46	0.1
Sc-47	10
Sc-48	0.1
V-48	0.1
Cr-51	10
Mn-52	0.1
Mn-53	1000
Mn-54	0.1
Fe-55	100
Fe-59	0.1
Co-56	0.1
Co-57	1
Co-58	0.1
Co-60	0.1
Ni-59	100
Ni-63	100
Zn-65	1
Ge-71	10000
As-73	100
As-74	1
As-76	1
As-77	100
Se-75	1
Br-82	0.1
Rb-86	10
Sr-85	1
Sr-89	10
Sr-90+	1
Y-90	100
Y-91	10

Nuclide	Clearance level (Bq/g)
Tc-96	0.1
Tc-97	10
Tc-97m	10
Tc-99	1
Ru-97	1
Ru-103+	1
Ru-106+	1
Rh-105	10
Pd-103+	1000
Ag-105	1
Ag-108m+	0.1
Ag-110m+	0.1
Ag-111	10
Cd-109+	10
Cd-115+	1
Cd-115m+	10
In-111	1
In-114m+	1
Sn-113+	1
Sn-125	1
Sb-122	1
Sb-124	0.1
Sb-125+	1
Te-123m	1
Te-125m	100
Te-127m+	10
Te-129m+	10
Te-131m+	1
Te-132+	0.1
I-125	1
I-126	1
I-129	0.1
I-131+	1
Cs-129	1
Cs-131	1000
Cs-132	1
Cs-134	0.1
Cs-135	10
Cs-136	0.1
Cs-137+	1
Ba-131	1

Zr-93	10		Ba-140	0.1
Zr-95+	0.1		La-140	0.1
Nb-93m	100		Ce-139	1
Nb-94	0.1		Ce-141	10
Nb-95	1		Ce-143	1
Mo-93	10		Ce-144+	10
Mo-99+	1		Pr-143	100

Nuclide	Clearance level (Bq/g)		Nuclide	Clearance level (Bq/g)
Nd-147	10		Th-228+	0.1
Pm-147	100		Th-229+	0.1
Pm-149	100		Th-230	0.1
Sm-151	100		Th-231	100
Sm-153	10		Th-232+	0.01
Eu-152	0.1		Th-234+	10
Eu-154	0.1		Pa-230	1
Eu-155	10		Pa-231	0.01
Gd-153	10		Pa-233	1
Tb-160	0.1		U-230+	1
Dy-166	10		U-231	10
Ho-166	10		U-232+	0.1
Er-169	100		U-233	1
Tm-170	10		U-234	1
Tm-171	100		U-235+	1
Yb-175	10		U-236	1
Lu-177	10		U-237	10
Hf-181	1		U-238+	1
Ta-182	0.1		Np-237+	0.1
W-181	10		Np-239	10
W-185	100		Pu-236	0.1
Re-186	100		Pu-237	10
Os-185	1		Pu-238	0.1
Os-191	10		Pu-239	0.1
Os-193	10		Pu-240	0.1
Ir-190	0.1		Pu-241	1
Ir-192	0.1		Pu-242	0.1
Pt-191	1		Pu-244+	0.1
Pt-193m	100		Am-241	0.1
Au-198	1		Am-242m+	0.1
Au-199	10		Am-243+	0.1
Hg-197	10		Cm-242	1
Hg-203	1		Cm-243	0.1
Tl-200	1		Cm-244	0.1
Tl-201	10		Cm-245	0.1
Tl-202	1		Cm-246	0.1
Tl-204	10		Cm-247+	0.1
Pb-203	1		Cm-248	0.1

Pb-210+	0.01		Bk-249	10
Bi-206	0.1		Cf-246	10
Bi-207	0.1		Cf-248	1
Bi-210	10		Cf-249	0.1
Po-210	0.01		Cf-250	0.1
Ra-223+	1		Cf-251	0.1
Ra-224+	1		Cf-252	0.1
Ra-225	1		Cf-253+	1
Ra-226+	0.01		Cf-254	0.1
Ra-228+	0.01		Es-253	1
Ac-227+	0.01		Es-254+	0.1
Th-227	1		Es-254m+	1

Appendix 4 *Rules for the application of nuclide-specific clearance levels*

1. When the nuclide-specific clearance levels are being applied, the sum of fractions of the clearance levels for the radionuclides present must be less than or equal to 1, i.e. the following summation formula shall be applied:

$$\sum_{i=1}^{n} \frac{c_i}{c_{FNi}} \leq 1$$

Where:
c_i is the total activity of nuclide i per mass unit or surface unit (Bq/g or kBq/m^2),
c_{FNi} is the clearance level for nuclide i, and
n is the number of nuclides occurring

2. The activity concentration of radioactive substances in materials subject to clearance may be calculated as a mean value of the entire quantity in question or a maximum of 1,000 kilograms. The limit of 1,000 kilograms is not applicable to thoroughly mixed liquids.

3. The clearance levels for rooms and buildings shall be applied to each square metre of the surfaces. Radioactive substances below surfaces are to be attributed to such surface and included when comparison is made with the clearance levels.

4. Daughter nuclides in accordance with Appendix 5 need not be included if their level of activity is lower than or the same as the level of activity of the parent nuclide.

5. If a radioactive substance without a specified clearance level occurs, the Swedish Radiation Safety Authority must be contacted for a decision on the clearance level to apply. For nuclides with half-lives shorter than 1 day, 0.1 becquerel per gram may be used as a default value.