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Swedish Radiation Safety Authority

2019:07

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

Decommissioning of the Barsebäck nuclear power plant in Sweden

Report number: 2019:07 ISSN: 2000-0456
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Abstract

The purpose of this report is to provide the European Commission with general data relating to plans for the decommissioning of the Barsebäck nuclear power plant, Barsebäck 1 and Barsebäck 2, that will enable the Commission 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 structure of the document follows the recommendations given in 2010/635/Euratom on the application of Article 37 of the Euratom Treaty.

Barsebäck 1 commenced operation in 1975 followed by Barsebäck 2 two years later. Both reactors were of the type boiling water reactors with a net electrical output 615 MW each. Barsebäck 1 and Barsebäck 2 were shut down permanently in 1999 and 2005 respectively, due to political decisions.

In 2006 the remaining nuclear fuel was transported off-site; since then Barsebäck nuclear power plant has been in Care and Maintenance operation and will continue to be so until 2020 according to current planning when dismantling and demolition is anticipated to start.

This report presents an assessment of the maximum expected emissions of radioactivity to air and water during decommissioning.

The assessment also includes a dose evaluation to a reference population living close to the power plant.

The dose to the reference group from radioactivity released during normal conditions at the plant is less than 0,003 μSv/year. As the dose to the reference group is less than 10 μSv/year, and there are no exceptional exposure pathways, no dose assessment is required for other EU member states.

The dose to the reference group from radioactivity released during a hypothetical radiological accident at the plant is less than 0,1 mSv.

As the dose to the reference group is less than 1 mSv, and there are no exceptional exposure pathways, no dose assessment is required for other EU member states

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This report has been completed by the Swedish Radiation Safety Authority, SSM, mainly based on information provided by the license holder, Barsebäck Kraft AB, BKAB. SSM has controlled that the general data provides the necessary information and that it follows the guideline of the most recent recommendations of the application of Article 37 of the Euratom Treaty.

Content

0. Introduction

The purpose of this report is to provide the European Commission with general data relating to the plans for decommissioning the Barsebäck nuclear power plant, comprising Barsebäck 1 (B1) and Barsebäck 2 (B2), that will enable the Commission to determine whether the implementation of the plans is liable to result in the radioactive contamination of water, soil or airspace of another European Union Member state. The decommissioning plan includes the construction of a new interim storage facility (interim storage 2) in order to provide required interim storage capacity.

This report follows the guidelines in Annex III (decommissioning of existing plant) and Annex II (construction of interim storage 2) of the recommendation of the application of Article 37 of the Euratom Treaty (2010/635/Euratom) [1]. At the beginning of each chapter in this report, the link to each Annex will be described. The report has been completed by the Swedish Radiation Safety Authority (SSM) mainly based on information provided by the license holder, Barsebäck Kraft AB (BKAB). SSM has controlled that the general data provides the necessary information and that it follows the mentioned guidelines [1].

According to the Swedish Nuclear Activities Act (1984:3), it is the obligation of BKAB, as holder of the nuclear licence, to decommission and dismantle the Barsebäck nuclear power plant (Barsebäck NPP).

The final goal for the decommissioning of the Barsebäck NPP is that the site shall be released from the regulatory control of the Nuclear Activities Act.

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

0.1. Barsebäck Nuclear Power Plant

The Barsebäck NPP is owned by Sydkraft Nuclear Power (SNP) and operated by BKAB which also holds the nuclear licence to operate and decommission the plant. SNP is a part of the Uniper Group, an international energy company active in the energy market extending from North America to Asia, with Europe and Russia being the core markets. The head office (Uniper) is located in Düsseldorf, Germany.

The Barsebäck NPP is situated in the southern part of Sweden on the west coast, 20 km north of the city of Malmö. The nearest European Union member state is Denmark, with its capital Copenhagen 20 km west of Barsebäck NPP.

B1 commenced operation in 1975 followed by B2 two years later. Both reactors were of the type boiling water reactors (BWR) with a net output (electrical) 615 MW each. B1 and B2 were shut down permanently in 1999 and 2005 respectively, as a result of political decisions.

B1 and B2 delivered 94 TWh and 108 TWh electricity respectively during their lifetime. In 2006 the remaining nuclear fuel was transported off-site to the Central Interim Storage Facility for Spent Nuclear Fuel (Clab) in Oskarshamn, owned and operated by the Swedish Nuclear Fuel and Waste Management Company (SKB), see Appendix 2. SKB is owned by the companies Vattenfall AB, Forsmarks Kraftgrupp AB, OKG Aktiebolag and Sydkraft Nuclear Power AB.

Barsebäck NPP has been in Care and Maintenance (C&M) operation since December 1, 2006. According to current planning dismantling and demolition (D&D) are anticipated to begin during 2020. During C&M operation extensive preliminary studies and analyses have been carried out as part of the decommissioning planning.

In 2015 BKAB filed a report in accordance with the requirements in Article 37 of the Euratom Treaty regarding dismantling of reactor internals at the Barsebäck NPP which was assessed by the Commission [2]. Since then the reactor internals from B2 have been removed and stored in interim storage 1 at the site (2017-2018). Reactor internals from B1 are being removed at present and placed in interim storage 1. All reactor internals will be stored in interim storage 1 in Q2 2019.

0.2. Decommissioning licensing procedures

In order to be granted a licence to commence decommissioning of Barsebäck NPP, including construction of interim storage 2, approvals are required from the following authorities:

- Swedish Radiation Safety Authority (SSM)

- Land and Environmental Court

- Local municipality

Swedish Radiation Safety Authority - SSM

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

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

Before the decommissioning of Barsebäck NPP can start, the safety analysis report (SAR) applicable to the decommissioning phase of Barsebäck NPP, must be reviewed and approved by SSM.

Before interim storage 2 can be constructed, the preliminary safety analysis report (PSAR) for the interim storage 2 must be reviewed and approved by SSM.

The review of the SAR for decommissioning of Barsebäck NPP and the review of the PSAR for the interim storage 2 are two separate processes (i.e. separate applications).

SSM also requires a decommissioning plan and a waste management plan for the decommissioning of Barsebäck NPP which will be reviewed together with the SAR. SSM's approval will be pending at least until the Commission has communicated its opinion on the General Data.

The SAR and accompanying reports will be submitted to SSM for approval in 2019.

After approval of the SAR, each work package for D&D containing contaminated or activated systems must be notified to SSM prior to commencement.

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

Regional Land and Environmental Court in Sweden

In order to ensure compliance with the rules of consideration in the Environmental Code, several environmentally hazardous activities and operations are subject to licensing. Activities or operations for which permits are compulsory are specified in the Environmental Code or in ordinances. D&D of a nuclear reactor requires a licence from the Land and Environmental Court. BKAB initiated the process of applying for a new licence for D&D with the Public Consultation in February 2018. The application also includes the construction of interim storage 2. The application has been submitted to the Regional Land and Environmental Court in 2018 for approval.

Local municipality

In accordance with the Planning and Building Act (2010:900), permit from the local municipality is required to erect interim storage 2 and to carry out conventional demolition of radiologically cleared buildings. The application regarding interim storage 2 will be submitted to the local municipality in 2019 for approval.

0.3. Decommissioning plan

The decommissioning plan includes the required activities in order for BKAB to perform the task of transitioning from C&M operation to the final end state which is to release the facility from the requirements stipulated in the Act on Nuclear Activities (1984:3) and the Radiation Protection Act (2018:396).

The end state will be achieved by meeting the following conditions:

- The radiological criteria for free release of material, buildings and land have been fulfilled, in order for the licence conditions to cease to apply to the facility.

- Conventional pollution will have been sufficiently removed so that the limits for less sensitive use of the land have been achieved.

- The site has been adapted in accordance with the owner's intentions.

In order to facilitate D&D a number of preparatory measures are required. The activities are planned to facilitate efficient waste management with clear processing paths and well-planned logistics as well as to enable free release.

Pending the completion of construction on SKB's final repository, SFR, to extend it for disposal of decommissioning waste, a new interim storage 2 will be constructed on the site in the harbour area, in order to provide capacity for temporary storage of the waste volumes created during decommissioning. Prior to construction, existing goods reception building must be demolished. The new interim storage will primarily be designed for short-lived very low-level waste (VLLW) and short-lived low level waste (LLW), but other radioactive waste, such as large components, may also be stored there. Interim storage 2 is planned to be constructed during 2020 and commissioned before use.

BKAB is planning to divide D&D for the entire site into two parts, the power plant area and the harbour area, see figure 0-1. This will lead to the end state for the facility being achieved in two separate stages, first for the power plant area and then for the harbour area.

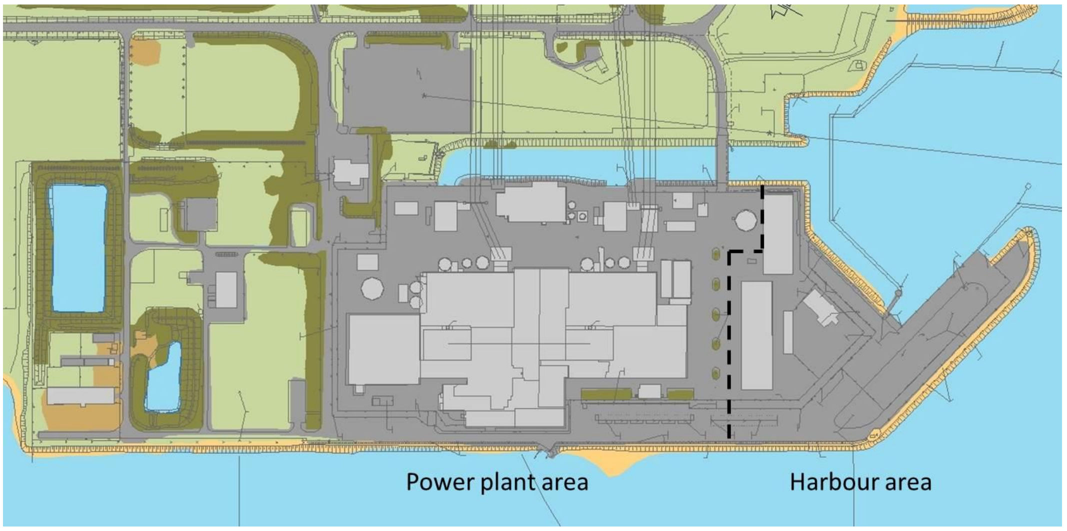


Figure 0-1. Power plant area and harbour area.

Power plant area
First the radiological dismantling of the power plant is carried out. The radiological dismantling is divided into the following eight decommissioning work packages:

1. Reactor pressure vessel
2. Biological shield / Neutron shield
3. System dismantling in reactor containment
4. System dismantling in reactor building
5. System dismantling in turbine building
6. System dismantling in waste building
7. System dismantling in other buildings
8. Decontamination of buildings and land

The radiological dismantling is expected to take approx. 7-10 years including free release of the buildings. Then the conventional demolition will commence and continue for approx. 3-5 years. Thereafter, the ground will be restored according to the final end state described above.

Harbour area
After radiological and conventional D&D are completed within the power plant area, interim storage of radiological waste will continue in the harbour area until such time it is possible to remove the waste.

D&D of the harbour area can commence when the radiological waste has been removed which is expected to take approx. 3-6 years, depending on the availability in SKB's transportation system. Thereafter the interim storages will be dismantled, free released and demolished in the same manner as the other buildings and the ground will be restored according to the final state described above, which will take approx. 2 years.

1. The site and its surroundings

Sections 1.1 and 1.3 - 1.5 are arranged in accordance with the requirements in Annex III and Annex II (2010/635/Euratom), thus applicable to both the existing plant to be decommissioned and the interim storage 2 to be constructed.

Sections 1.2 and 1.6 are arranged in accordance with the requirements in Annex II (2010/635/Euratom), thus applicable to the interim storage 2 to be constructed.

1.1. Geographical, topographical and geological features of the site and region

The Barsebäck plant is located in southern Sweden, in the municipality of Kävlinge on the west coast of Skåne, in an area of high natural value and cultural significance.

The power plant facility is located on the shore of Öresund, about 20 km north of the Swedish city of Malmö and about 20 km east of the Danish capital of Copenhagen. The coordinates for the facility according to WGS84 are N 55º 44’and E 12º 55’. The nearest settlement is the fishing village Barsebäck harbour, which extends between 500 and 1’500 metres north of the facility. The settlement Löddeköpinge is located about 7 km east of the facility and the towns of Landskrona and Lund are located between 15 and 25 km from the Barsebäck plant.

The closest European Union Member State is Denmark; about 20 km west of the Barsebäck plant. Germany is located about 150 km to the south. Poland is located about 250 km southeast of the facility. See figures 1-1 and 1-2 for location and table 1-1 for distances and number of inhabitants of urban areas in neighbouring countries.

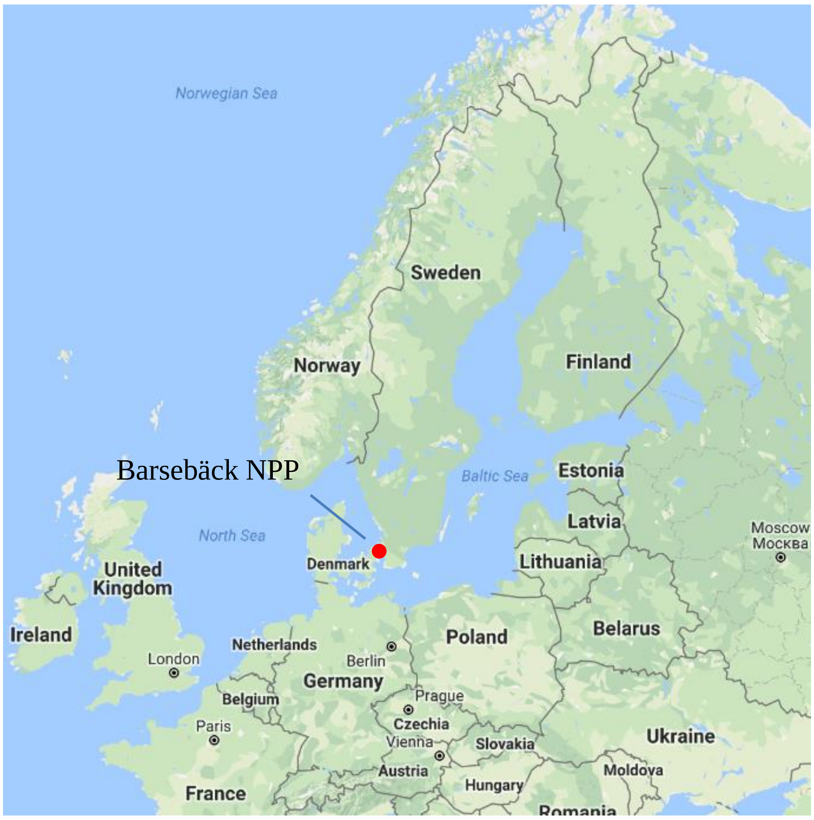


Figure 1-1. The location of the Barsebäck NPP (source: Google maps).

Figure 1-2. The location of Barsebäck NPP (source: County administration Webb-GIS).

Table 1-1. Barsebäck NPP neighbouring states (source: https://se.avstand.se and Eurostat).

Nation	Distance to border from Barsebäck NPP (km)	Urban region	Number of in-habitants 2018-01-01 (millions)	Distance to urban area from Barsebäck NPP (km)
Denmark	20	Copenhagen	2,0	20
Germany	150	Berlin Hamburg	5,2 3,3	360 310
Poland	250	Warszawa	3,4	650
Holland	500	Amsterdam	2,7	650
Lithuania	500	Vilnius	0,8	800
Latvia	500	Riga	0,6	700
Estonia	800	Tallinn	0,6	810
Finland	800	Helsinki	1,6	860

Barsebäck NPP is situated primarily on top of raised land. The original site, which has been affected by the construction of the plant, consisted of sea, sand banks, pastures and wet meadow. In the power plant area the top layer consists of support material, gravel, rock and boulders. The facility is a dominating feature in the area. The highest point is the stack at 113 metres above sea level (i.e. 110 m above ground level). Other buildings are up to 60 metres above sea level.

The bedrock in the immediate area consists of sediment rock, lime stone, which are superimposed by watery sediment. Specifically on the Barsebäck peninsula there is a top layer of moraine clay. In the area to the north and south of the Barsebäck peninsula instead of moraine there are large areas of lighter sandy soil.

1.2. Seismology

Barsebäck NPP as well as other industrial facilities were designed without special consideration of earthquake loads. This will also apply for the new interim storage 2 to be constructed. The reason for this is that Scandinavia is considered to have seismically stable bedrock and in conjunction with the design of the Barsebäck NPP the risk for significant earthquakes that could damage the plant was deemed to be negligible. Earthquake is also during D&D considered to be a hypothetical event (frequency <10-5 per year).

The comprehensive work to develop the ground response envelope spectra for Sweden was performed in the late 1980s and early 1990s in a joint venture project with the Swedish Nuclear Power Inspectorate, Vattenfall, Sydkraft and OKG [3]. The seismicity is defined by the average Fennoscandian seismicity function. Fennoscandia is the area the site belongs to with respect to seismicity. The transmission of seismic waves from the source to the surface of the ground is through hard rock modelled with the average properties of Swedish bedrock with respect of their effects on the wave propagation.

For earthquakes with a Richter magnitude up to 4,5, there are sufficient statistics in the region to find geological/geographic links, while this is not guaranteed for higher magnitudes. In more seismically active regions of the world, with known active rejections, there is a linear link between small and large earthquakes. For southern Sweden, however, there are no known active rejections. On the other hand, single earthquakes with magnitudes above 4 occur in areas without elevated seismicity. It has therefore not been possible to determine a maximum possible earthquake in the region or a regional distribution of major earthquakes, but it is assumed conservatively that these have an even distribution across Scandinavia.

1.3. Hydrology

The Recipient Öresund

The power plant area is located directly adjacent to Öresund, which is the straight between Sweden and Denmark that connects the Baltic Sea with the Kattegatt Sea. Together with Little Belt and Great Belt Öresund is inlet and outlet for the Baltic Sea's natural circulation of seawater.

The coastal area around the Barsebäck NPP is characterised by flat wet meadows towards the sea, sand banks, pastures and sandy beaches. This coastal area is the least exploited coastal stretch in Skåne and is part of an area of national interest according to chapter 4 in the Environmental Act[1]. Three nature reserves are located in the area where the shallow bay, Salviken, located to the south of the plant is particularly important to birdlife.

The cooling water canal that previously supplied B1/B2 with cooling water, runs east of the facility through an open canal from Salviken to the facility. The cooling water was returned to the sea via underground tunnels with outlets at the beach on the western side of the facility, see figure 2-1 in section 2.1.

Process discharge water from the internal purification facility that contains radioactive substances is discharged in outbound cooling water tunnels after approved sampling, see section 2.3.

The coastal area on the Swedish side of Öresund is very shallow. As an example, the sea depth at about 500 metres from the shoreline at the power plant is only 6 metres. The plant has a pier and a channelled approach that is maintained at 6 metres free depth through dredging.

The currents in Öresund are primarily driven by the differential in water level between Kattegatt in the north and the southern part of the Baltic Sea and are mainly north to south in direction. There is very rarely any transport of water across the sound. The winds in the area are important as westerly winds lower the water level in the south Baltic and raise the water level in southern Kattegatt, which results in a southerly current through the sound.

[1] Swedish environmental law, Environmental act (1998:808), chapter 4 concerns regulations of land and water for certain areas.

Easterly winds cause the opposite effect, resulting in a northerly current. Overall it is possible to rely on a northerly current 60% of the time and 30% southerly current with 10% of the time a lull in the current.

Table 1-2 contains information on average water level, maximum and minimum levels in Barsebäck, based on single measurements performed between 1937 and 1993.

Table 1-2. Water level in Barsebäck measured 1937-1993.

	Level, cm	**Date recorded**
Highest recorded water level	101	1962-02-17
Average, annual highest water level	70	
Average, annual lowest water level	-54	
Lowest recorded water level	-97	1941-11-12

From 1992 the water level in Barsebäck is continuously registered by the Swedish Meteorological and Hydrological Institute (SMHI) [43].

The tide in the open section of Öresund outside Barsebäck is about 10 cm while at Barsebäck it is 3-4 cm. The duration that is most prevalent is 12 hours, but it is superimposed on a variation that recurs every 24 hours.

Future water level

Risks of future flooding of the facility due to raised sea water level are very small. SMHI has calculated that future high water levels, with 100 year recurrence and raised average water level included, may in the worst case scenario be calculated at +2,1 metres for Barsebäck NPP [4]. The facility's ground level (including future interim storage 2) is located 3,0 m above today's normal water level. Historically the Barsebäck facility has never experienced water levels that have caused flooding of roads or courtyards.

Meteorological calculations by SMHI show that future (2070-2100) average water levels due to climate change will be around 0,22-0,72 m above today's values [4].

Ground water

Geologically the Barsebäck plant is located on top of the so-called Alnarp valley, a tectonic valley in the limestone bedrock, in which the ground water Alnarp current is located. There was a committee established in 1964 to study and map the hydraulic conditions for the optimum utilisation of the Alnarp current, see figure 1-3.

The Alnarp current [44] denotes the area between the watersheds, according to the overview below, as well as the aquifer located in the Alnarp valley and quaternary layers and limestone bedrock whose water flows towards Öresund. The Alnarp current is one of Sweden's largest ground water reservoirs and covers a surface area of about 625 km^2. The Alnarp valley bottom is located about 60 metres below Barsebäck NPP and the largest currents can be found in the sediments just above the bedrock surface or in the bedrocks' fissured top layer.

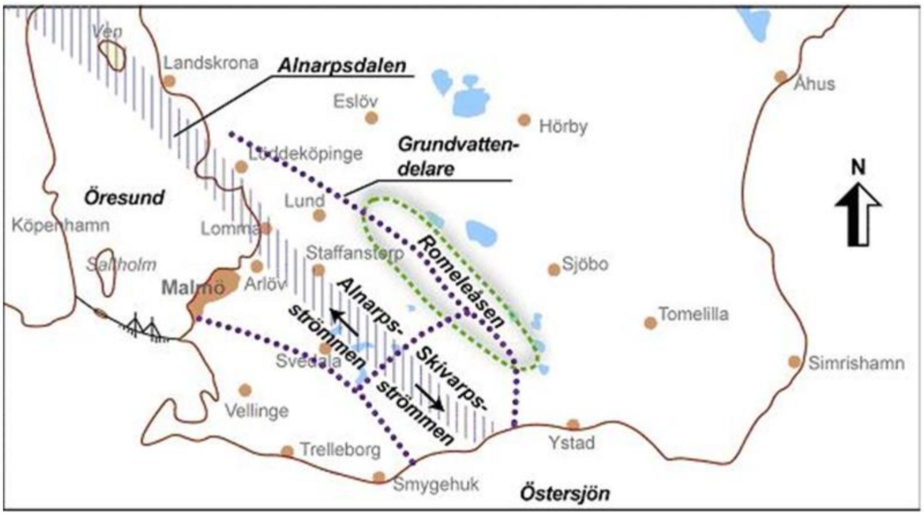


Figure 1-3. Overview of the Alnarp current

The Alnarp current has a maximum capacity of 25 million m^3 per year. The largest extractions were made in 1948 and in 1971 with about 18 million m^3 per year. Thereafter the extractions have been declining to under 10 million m^3 per year in most recent years.

Due to the aquifer being covered by extensive layers of moraine clay the water is fairly well-protected from pollution.

A shallower ground water layer exists above the moraine layers, about 1-2 metres below the surface, and following the surface. At Barsebäck NPP the ground water flow is directed from the east towards Öresund.

The Alnarp current flows towards the north west and after passing under the Barsebäck NPP continues out into Öresund, passing the island Ven and further in under Själland. The settlement northwest of the power plant, Barsebäck harbour, is connected to the municipal drinking water network which is not sourced from the local ground water.

1.4. Meteorology

In order for different locations' climate data to be compared, the data must reflect the same time period. The World meteorological organisation (WMO) has therefore decided that statistical parameters that are to be used for describing climate are to be calculated for so-called climatological normal. The normal are most often calculated over consecutive periods of 30 years, where 1961-1990 is the current climatological standard normal. Temperature- and precipitation data for Malmö are given.

The area surrounding Barsebäck is dominated by westerly winds with an average wind speed of about 7 m/s. Wind speeds in excess of 15 m/s occur 1% of the time. The highest wind speeds in Sweden occur during tornadoes where the wind speeds may briefly reach 70-100 m/s. The probability of a tornado occurring at Barsebäck is assessed to be 10^{-5}/year. For normal winds the maximum 50-year value is 45 m/s. See table 1-3.

Table 1-3. Wind frequency and wind direction at Barsebäck NPP (1987 - 1992).

Speed [m/s]	N	NE	E	SE	S	SW	W	NW	Cumulative
0,5-2,5	2,0	2,1	3,6	1,5	1,5	1,0	1,5	1,9	15,1
2,5-4,5	2,4	2,3	4,5	2,6	2,8	2,6	3,4	3,2	23,8
4,5-6,5	1,7	1,4	3,4	2,5	3,0	3,5	4,4	3,2	23,1
6,5-8,5	0,87	0,60	1,9	1,8	2,4	3,3	4,0	2,6	17,5
8,5-10,5	0,36	0,20	0,88	0,99	1,5	2,3	2,8	1,7	10,7
10,5-12,5	0,13	0,05	0,34	0,43	0,78	1,3	1,6	0,93	5,5
12,5-14,5	0,04	0,01	0,11	0,14	0,33	0,54	0,71	0,44	2,3
14,5-16,5	0,01		0,03	0,04	0,11	0,18	0,26	0,18	0,81
16,5-18,5			0,01	0,01	0,03	0,05	0,08	0,06	0,24
18,5-20,5					0,01	0,01	0,02	0,02	0,06
Cumulative	**7,5**	**6,6**	**14,7**	**10,0**	**12,5**	**14,8**	**18,8**	**14,2**	**99,1**
Calm									**0,9**

Normal annual precipitation for the area is 600 mm (average for the period 1961 - 1990), about 10% in the form of snow. The largest recorded amount of daily precipitation for Malmö is 65 mm. If a larger amount of precipitation occurs in a short time the term cloud-burst is sometimes used as it is experienced as intense and fierce. Cloudburst is defined as at least 50 mm in an hour or at least 1 mm per minute. In Sweden the highest recorded daily precipitation is about 300 mm. The upper limit for possible rates of precipitation is between 300 and 400 mm per day. In extreme cases it has been assessed that the rate of precipitation for 10 minute duration, may reach 35 to 50 mm. The frequency of a 10 minute period of precipitation of 20 – 25 mm is considered to be 10^{-2}/year.

The average monthly temperatures are 17℃ for the warmest (July) and -0,2℃ for the cold-est (January and February). The highest recorded temperature in Malmö since 1936 is 34,0℃ and the lowest -28,0℃.

The air pressure is generally between 950 – 1050 hPa. Normally the air pressure in the area close to Barsebäck NPP and the coast of Öresund is about 1010 hPa. On rare occasions these limits may be undershot or exceeded. The lowest air pressure recorded in Sweden is 937,2 hPa and the highest 1063,8 hPa. An air pressure change of about 10 hPa/hour has been observed in Scandinavia. Such a precipitous fall in air pressure is assessed to occur once every 100 years. During a low pressure over the Atlantic an air pressure change of 53 hPa/hour was observed. A change of this magnitude is extreme and can be used as an upper bound for rapid air pressure transient over Sweden. The lowest and highest air pressures have the highest frequency during the winter months.

1.5. Natural resources and foodstuffs

Potable water is distributed by the municipality of Kävlinge to all households in the urban areas. The Barsebäck NPP is also supplied from the council's potable water network via piping from Löddeköpinge. The water source for the municipal water is the lake Bolmen, about 170 km north of the plant. For irrigation of crops in nearby agrarian areas, ground water or water from local irrigation dams is used. The area surrounding Barsebäck NPP does not supply any neighbouring country with water.

The majority of the land closest to the Barsebäck NPP is used for agricultural cultivation. The growth season is on average 200 days with an average temperature of 13℃. The prevalent soil type is muddy moraine or moraine clay as well as sand and gravel. The dominant crops are cereals, sugar beets, root crops and pees. There is pasture for beef cattle and a few dairy farms.

Woodland is located within Järavallen's nature preserve, 5 km north of Barsebäck NPP as well as Sandskogen near Löddeköpinge, 5 km to the east. Within the area there are three bathing areas within a radius of about 4 km from the facility.

In Lomma harbour there is a number of professional fishermen. Otherwise fishing is only practiced for private consumption. The professional fishing is primarily conducted in Kattegatt and the Baltic Sea and only to a very limited extent in Öresund.

Normally Swedish territorial waters are located 12 nautical miles between Sweden and Denmark, but in Öresund there are no international waters due to the short distance between the countries.

The Swedish export of agricultural goods and foodstuff is steadily increasing. The export consists primarily of fish, various foods, grains and beverages. These product groups represent 75% of the total value of foodstuff export. Product types that clearly have increased in export value are fish, fruit and vegetables, oils and fats, sugar, coffee etc. as well as tobacco. Norway is the most important export market followed by Poland, France, Denmark, Great Britain, Finland, Germany, Spain, Italy and the Netherlands [5].

1.6. Other activities in the vicinity of the site

The closest nuclear facility is Ringhals NPP, which is located about 200 km north of Barsebäck NPP and about 70 km south of Göteborg. There are no other facilities in the vicinity that can contribute to the radiological discharges, and it is therefore only the discharges from B1 and B2 that are reported.

The European spallation source (ESS) is a research facility under construction in Lund 27 km east of Barsebäck NPP. A neutron source will be built for the purpose of studying materials at molecular and atomic levels. The ESS is not a nuclear facility, but it will create radioactive material [45].

Conventional power plants and combined heat and power plants are located in Malmö and Lund.

In the municipality of Kävlinge, where Barsebäck NPP is located, only start-up of smaller new businesses with low interference potential occurs.

About 200 m to the east of Barsebäck NPP, a gas turbine power plant and associated oil cisterns are located that are owned by Uniper/Thermal Power. Associated switchyards for 400- and 130 kV power lines are owned by Svenska Kraftnät and E.ON Elnät respectively.

Otherwise in the surrounding area of Barsebäck NPP there is no industry posing environmental hazards, military facility, pipeline or storage depot that may affect the activities.

On the European road E6, about 6 km east of Barsebäck NPP, hazardous goods are transported by truck. Hazardous goods are also transported by railroad which is located about 15-20 km east of Barsebäck NPP.

Öresund is a heavily trafficked sound with some dangerous goods transports. The coast guard is responsible for emergency preparedness and for responding to any accidents at sea. In the sea outside Barsebäckk NPP there is an area where ship traffic is prohibited. In addition to this area, traditional maritime traffic rules apply

The nearest airport is Kastrup, adjacent to Copenhagen on the far side of Öresund, about 20 km to the west of Barsebäck NPP.

There is no need for any additional protection measures against external events caused by human activities.

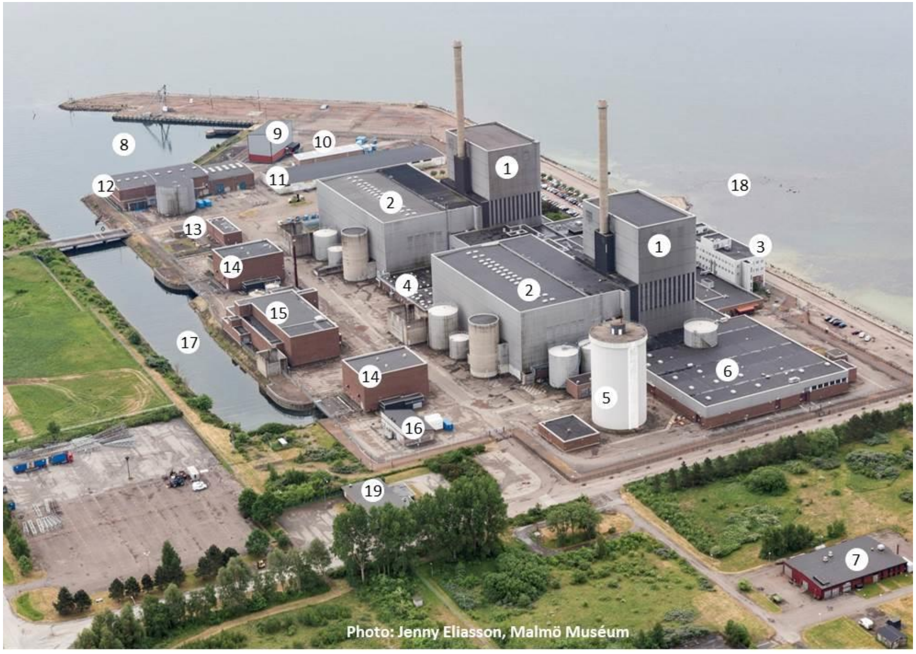
2. The installation

Sections 2.1 - 2.5 are arranged in accordance with the requirements in Annex III (2010/635/Euratom), thus applicable to the existing plant to be decommissioned.

Section 2.6 is arranged in accordance with the requirements in Annex II (2010/635/Euratom), thus applicable to the interim storage 2 to be constructed.

2.1. Brief description and history of the installation to be dismantled

Barsebäck NPP consists of two adjacent nuclear reactors, B1 and B2, see figure 2-1 below. B1 and B2 are structurally joined via electrical buildings, control rooms and staff buildings. Some process systems are common for both B1 and B2. As both B1 and B2 have a lot in common and have been shut down for such a long period, they are now considered to be one facility.



1. Reactor building
2. Turbine building
3. Office building
4. Electrical building
5. FILTRA
6. Service building 1
7. Service building 2
8. Harbour
9. Interim storage 1
10. ATB-storage
11. Location of the planned interim storage 2
12. AB- and C-storage
13. Water treatment facility
14. Sea water cleaning facility
15. Liquid waste facility
16. Hydrogen gas production facility
17. Cooling water inlet
18. Cooling water outlet
19. Information center

Figure 2-1. Barsebäck nuclear power plant. Note that no. 11, pointing out location of the planned interim storage 2, actually shows the goods reception building that will be demolished in favour of interim storage 2.

After final shutdown a lot of the buildings have been assigned a new or modified function and the majority of the process systems are shut down. The systems that will be operational during D&D are primarily ventilation, activity monitoring, fire protection, electrical power and security, as well as the systems needed for proper management of the waste and storage of radioactive waste.

Spaces where there is a risk of radioactive substances being discharged to water or air, or being transferred with goods or personnel to the environment are classed as controlled areas for example spaces inside the reactor- and turbine buildings, the waste building and service building 1.

Status of the facility prior to D&D
Since the final shutdown a number of preparatory activities have been performed. For example, all nuclear fuel, all control rods and core probes as well as sampling rod chains belonging to B1 and B2 were removed from Barsebäck NPP and sent to Clab. System decontamination of primary systems was performed 2007-2008, which resulted in significant amounts of the activity inventory being transferred from system surfaces to tanks storing used ion exchange resins. Many systems have been shut down during the C&M operation, as they are no longer needed for operational or safety reasons.

During 2006-2008 the facility's electrical systems and control and surveillance systems were adapted to better suit the requirements during C&M operation. The changes also entailed the implementation of energy-saving measures. Considering the measures already implemented it is not envisaged that any major modifications of the facility are needed to facilitate operation and surveillance of the plant during D&D.

Radiological surveys has been performed and will continue during D&D.

In 2016 interim storage 1 was constructed to store the segmented reactor internals. Other low and intermediate level waste might be stored in interim storage 1.

Reactor buildings
Each reactor building consists of three main sections; reactor containment, storage and handling pools as well as the rest of the structure.

Each reactor building consists of 11 floor levels. The reactor containment, a cylindrical space, is located in the centre of the building. The top part contains the reactor together with ancillary equipment and the lower part contains the suppression pool. In the event of an abnormal situation occurring during operation the containment prevented discharge of activity to the environment.

The top floor of each reactor building contains the reactor hall with the storage and handling pools, which among others functions provided storage for irradiated fuel, control rods and the reactor pressure vessel head and dome during outages.

Other parts of each reactor building contain mainly adjacent process systems and service areas.

The foundation of each reactor building is located on top of firm moraine clay 13 m under the plant's courtyard. The surface area above ground of each building is about 33 x 46 m and the height above ground is about 70 m, (110 m including the stack). The outer walls consist of aluminium-clad concrete.

Turbine buildings
Each turbine building consists of two main sections: the turbine section and the feed water preheating section.

Each turbine section contains mainly the turbine, condenser and generator while the feed water preheating section contains spaces for feed water preheaters, condensate polishing equipment and feed water pumps.

Each turbine building's load-bearing pillar and wall foundations are located on firm moraine clay while the concrete floor foundation rests on packed gravel. The surface area above ground of each building is about 86 x 53 m and the height above ground is about 32,5 m. The outer walls consist of aluminium and brick-clad injected polymer concrete.

Office buildings
The Barsebäck NPP also has office buildings, kitchen, staff canteen and buildings for the presentation of external information, which will also be used during D&D, for as long as they are needed.

Electrical buildings
Each electrical building is separated into 7 floor levels of which the three lowest levels contain cable spaces. Otherwise the electrical buildings contain spaces for electrical systems such as batteries, switch gear and frequency converters as well as some offices.

Each electrical building's load-bearing pillars and walls are underpinned in sockets located in firm moraine clay while the concrete floor in the cable basement's foundation rests on top of packed gravel. The surface area above ground of each building is about 90 x 28 m and the height above ground is about 22 m. The outer walls consist of aluminium and brick-clad injected polymer concrete.

Filtra
Filtra is a pressure relief and scrubbing system that has been shut down. The purpose of Filtra, in the event of an accident, was to protect the environment from radioactive releases. Filtra is a 40 m-tall tower, filled with 10'000 m^3 of crushed rock and gravel.

Service building 1
In service building 1 there are facilities for handling, sorting and compacting solid waste and for separating waste oil, as well as a decontamination facility for tools, equipment and components. The radioactive waste is sorted according to waste category and radiation classification. The sorted and classified radioactive waste is sent to external facilities either for incineration, smelting or final disposal.

Harbour
The Barsebäck NPP's harbour is located directly adjacent to the power plant area and is equipped with electrical supply for ships. The harbour is fenced and is subject to the same security requirements as the power plant. The purpose of the harbour is the handling of radioactive waste in connection to maritime transport. The harbour can also handle other types of traffic such as vessels performing hydrographic surveys, moorings for rescue boats as well as other traffic important for the plant's activities. The harbour is classified by the International Ship and Port Facility Security Code (ISPS-code). The harbour is classified as a civilian protected property by the county council of Skåne.

Interim storage 1
Interim storage 1 was constructed in anticipation of D&D of the whole plant in order to store segmented reactor internals until such time they can be transported to their final repository, which has been presented earlier in a separate Article 37 report, assessed by the Commission [2]. There will be remaining capacity in interim storage 1 even after the segmentation of reactor internals is complete, which means the facility can be used as interim storage for other radioactive waste.

The building consists of one floor divided into a main building (storeroom and anteroom for loading and unloading) and an auxiliary building (electrical room and office).

The main building is provided with dehumidification and heating equipment. The air recirculates in this part of the building i.e. no emission point to the surroundings exist.

The auxiliary building is provided with conventional air-treatment equipment and has emission points to the surroundings.

The foundation of the main building consists of a heavily reinforced concrete slab with a surface area above ground of about 33 x 15,5 m, located at 3 m above average sea level. The structure consists of steel-clad and uninsulated thick concrete walls. The auxiliary building is a more conventional structure that is insulated and has a surface area above ground of about 11 x 4,5 m.

ATB-storage
Waste transport container, ATB, is a transport package for waste containers. The ATB-storage stores shipping containers and ATBs containing low and intermediate level waste awaiting transport to external waste treatment facilities or final disposal.

The building consists of one floor and it is provided with natural draft ventilation. The load-bearing walls are attached to a concrete slab, which is resting on top of packed gravel and moraine clay. The surface area above ground is about 41,5 x 10 m and the height of the building above ground is about 6 m.

AB- and C-storage
The AB- and C-storage were designed to provide radiologically protected storage for short-lived low and intermediate level waste. The walls and other structures of the building function as radiation shielding as well as load-bearing elements. The ventilation functions include dehumidification and maintaining a comfortable working environment. The air in the handling spaces and the storage compartment is recirculated. Solid waste is stored in the AB-storage, for example solidified ion exchange resins. The waste is stored in concrete moulds and placed in cells covered with radiation-shielding concrete blocks. Steel drums containing low and intermediate level waste and scrap metal are stored in the C-storage. The C-storage is also used to store concrete tanks filled with filter waste/ion exchange resins pending transportation. The waste is stored pending further external conditioning or final disposal. The surface area above ground is about 30 x 80 m and the height of the building above ground is about 13 m / 9,5 m.

Sea water cleaning facility
There are two sea water cleaning facilities at the Barsebäck NPP with the function to screen sea water. The screening plant for B1 has already been shut down. At B2 one cooling water pump is intermittently operated during C&M operation in order to provide enhanced flow when treated wastewater is discharged to Öresund. Only limited amounts of debris arise during these short periods of operation.

Liquid waste facility
A common liquid waste facility at the Barsebäck NPP treats different streams of radioactive water. The liquid waste facility is a freestanding building where radioactive effluents and discharged ion exchange resins are transported via piping. The facility separates the solid component and purifies the water. After sample approval the water is pumped out to sea.

Cooling water inlet and outlet
The cooling water was extracted from Öresund via the harbour and a common intake canal to the facility. The intake canal is situated south of the NPP. The cooling water was discharged to the west of the NPP. As during C&M operation, there is no need for cooling water during D&D as all of the fuel has been removed. During C&M operation, one cooling water pump is intermittently in operation for other reasons, see sea water cleaning facility above.

Other buildings
There are stores, workshops and warehouses to facilitate service and maintenance of the Barsebäck NPP. The laundry facility used to wash protective clothing in the controlled area was shut down in 2009. The laundry is currently transported to an external laundry facility.

There is a hydrogen production plant located at the Barsebäck NPP. During power operation hydrogen gas was added to the reactor coolant in order to reduce the risk of stress corrosion cracking of the reactor piping by reducing the amount of free oxygen in the coolant. The hydrogen plant has not been used during C&M operation and will not be used during D&D.

There are two natural gas fired boilers, one primary and one reserve, to heat the facility. For production of hot water there are electrical water heaters placed around the facility.

The Barsebäck NPP onsite water works distribute potable water, water for fire hydrants and water for production of process water. Incoming water is potable water from Kävlinge municipality. The process water used at the facility is deionised and produced at the Barsebäck NPP in the water treatment facility.

2.2. Ventilation systems and the treatment of gaseous and airborne wastes

There are separate ventilation systems for B1 and B2, servicing different spaces. One system is dedicated to non-controlled areas and one system is dedicated to controlled areas.

Spaces within controlled areas include the reactor, turbine and waste buildings, service building 1, parts of the electrical buildings and parts of storage areas. These spaces are ventilated through separate ventilation systems, where directed ventilation guides the air to the atmosphere via the ventilation stacks installed on B1 and B2 as well as service building 1.

As BKAB has removed all fuel from the site, SSM has granted an exemption [6] regarding the requirements for continuous nuclide-specific measurement of noble gases, nuclide-specific measurement of iodine sampling, as well as carbon-14 and tritium in discharges to atmosphere. The analyses currently performed on atmospheric discharges are nuclide-specific gamma measurements on aerosols collected on sampling filters integrated weekly, see section 3.3.

Discharge of radioactive substances from the Barsebäck NPP to air is monitored by sampling at the discharge points:

- main ventilation stacks on top of the B1 and B2 reactor buildings,
- ventilation stack on top of service building 1.

The atmospheric discharges from controlled areas are monitored by continuously diverting a small portion of the airflow over a sampling filter for aerosols. Sampling filters are analysed once per week for radioactive substances.

Sampling volume and discharged air volume are measured and recorded in order to calculate the total discharge of radioactivity to the atmosphere.

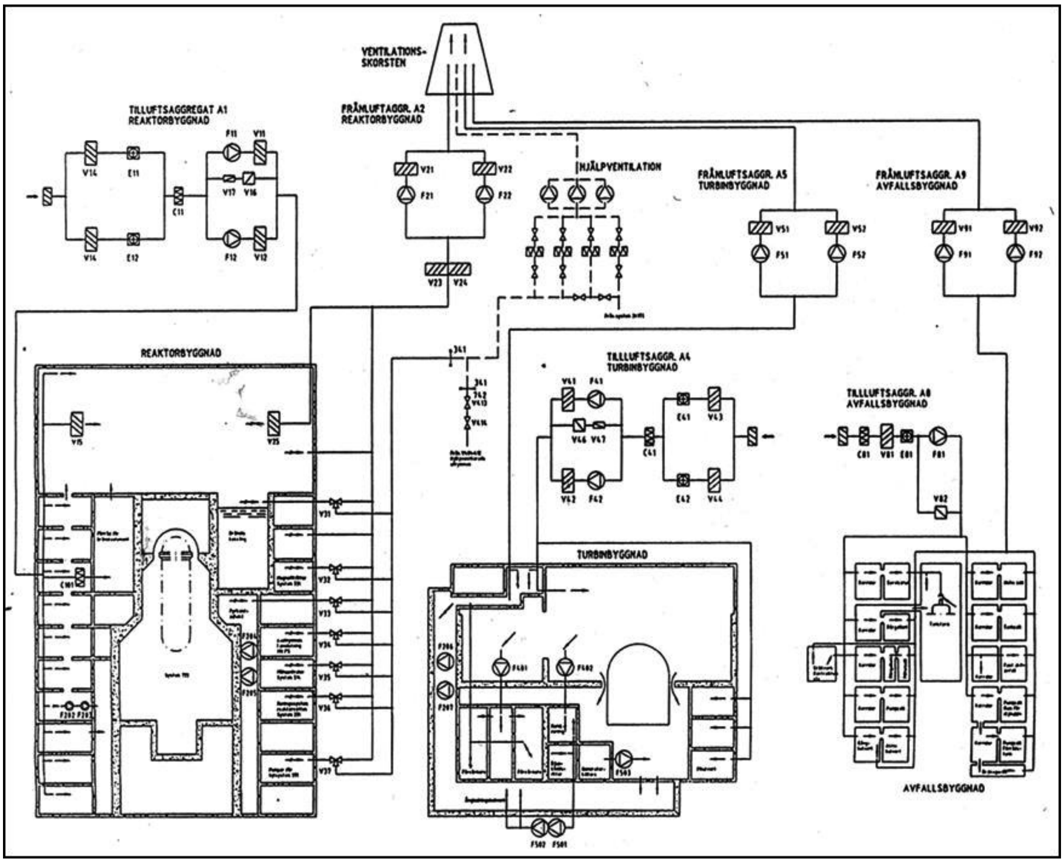


Figure 2-2. Schematic of the ventilation systems at B1before reconstruction during D&D

Currently the air extracted from the waste building is led to the atmosphere via the turbine building at B1 and main ventilation stack on top of B1, see figure 2-2. During D&D the ventilation of the waste building will be modified. By separating the waste building from the reactor and turbine buildings at B1 interdependency between these buildings and the waste building's ventilation requirements will thus be eliminated during D&D.

It is possible a mobile ventilation system may be required for a short duration during dismantling of current ventilation equipment.

The interim storage 1 (main building) and AB- and C-storage are not provided with exhaust air ducts, the indoor air recirculates. The ATB-storage is provided with natural draft ventilation.

2.3. Liquid waste treatment

B1 and B2 share a common liquid waste treatment facility to manage radioactive water. The liquid waste facility is a freestanding building, see figure 2-1. The purpose of the facility is to separate the solid fraction and purify the remaining water as well as discharge the purified water to Öresund after approved sampling. During C&M operation a cooling water pump at B2 is used for discharge in order to fulfil the mixing requirement for discharging water from the waste building. During D&D this pump will be disconnected. The radiological effect from the reduced mixing flow has been investigated and reported [7]. The assessment is that the reduced mixing flow does not have any significant radiological effect to humans or the environment.

During power operation about 50’000 m^3 of water was processed annually. During C&M operation the amount has decreased to about 2’000 m^3/year. During D&D this number is expected to decrease even further, especially after all the storage pools have been emptied of water. Sedimentation in tanks therefore becomes more efficient as the flow rates are low.

Barsebäck does not have any laundry facility on site and furthermore the use of chemicals has been minimised and the use of strong complexing agents is prohibited within the controlled area. Altogether this results in high efficiency of the ion exchange filters (resins).

The radioactive water’s origins and composition do differ. In order to facilitate an efficient treatment the waste facility is subdivided into different trains. A schematic overview is shown in figure 2-3.

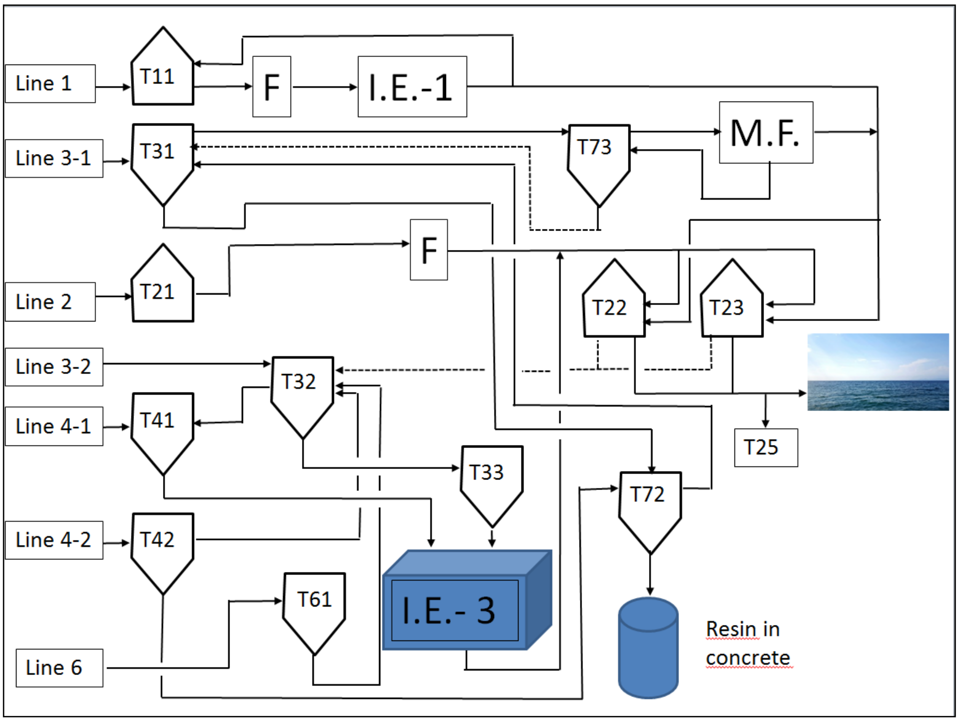


Figure 2-3. Schematics of the waste facility, train 1-6.

Train 1	System drains from reactor buildings.
Train 2	Floor drains from reactor- and turbine buildings as well as service building 1.
Train 3-1	Ion exchange resins from systems for purification of storage pool water.
Train 3-2	Water from floor drains and decontamination systems.
Train 4-1	Precoated filters and ion exchange resins from the waste treatment facility.
Train 4-2	Beaded ion exchange resins from the waste facility.
Train 5	Evaporator – train 5 is not in operation.
Train 6	Floor drains from the waste facility.
Train 7	Train for management of ion exchange resins and particular pollutants from train 3 and train 4.

Abbreviations:

F	Precoat filters for capture of particulates.
I.E.-1	Deep bed ion exchangers containing beaded ion exchange resin.
M.F:	Membrane filter for capture of particulates > 1 nm.
I.E.-3	Deep bed powder ion exchanger for capture of ions and particulates and silt from floor drains. The purification step is performed in a concrete tank with dewatering.

Train 1: In tank T11 water for purification from the reactor building's system drains, including storage pool water, is collected. Purification is performed intermittently in a recirculating purification system composed of filters and ion exchangers. The water is purified to low activity levels before it is transferred to discharge tanks T22 or T23.

Train 2: Water from floor drains within controlled areas comes from spaces within the reactor building, turbine building as well as service building 1. The water is directed to the waste facility for treatment. After sedimentation and filtering the water is led to the discharge tanks T22 or T23.

Train 3-1: In tank T31 spent powdered ion exchange resin from systems for purification of storage pool water is collected. The clear phase in the tank is allowed to settle before the water is pumped to T73. The activity in T73 is concentrated by membrane filtration. The permeate is pumped to discharge tanks, while the concentrate is intermittently returned to T31. Powdered ion exchange resin is transferred to tank T72 in train 7.

Train 3-2: T32 is used as a settling tank for contaminated process water. The clear phase in T32 is directed via T41 to concrete tanks (I.E.-3) containing spent powdered ion exchange resin from the condensate polishing system. After purification by the concrete tank's powdered resin the water is moved to discharge tanks T22 or T23. The sediment in T32 is moved to T33 which is intermittently emptied into the concrete tanks.

Train 4-2: T42 is a buffer tank for beaded ion exchange resins from the reactor buildings and the waste facility's ion exchange resins from train 1. The clear phase from T42 is transferred to T32. Ion exchange resins are transferred to tank T72 in train 7.

Train 6: In tank T61 system- and floor drainage from the waste facility is collected. The drainage is directed towards the concrete tank via T32 and T33.

Train 7: In tank T72 ion exchange resins are collected to be grouted into 200-litre barrels. Surplus water from T72 is returned to T31.

From the discharge tanks T22 and T23 discharge to sea is conducted intermittently after activity measurements. During the discharge a proportionate sample is extracted for legal sampling in T25. See further information in section 4.3.

In summary regarding treatment of liquid waste:

- Purification of water is performed by:
    - Sedimentation
    - Recirculated filtering of water in tank T11
    - Membrane filtering of highly contaminated water
    - Filtering of water with lower level of contamination in concrete tanks with powder form ion exchange resin.
- Transported out from the waste facility are:
    - Purified water to sea
    - Concrete tanks containing low level dewatered powder form ion exchange resin and silt
    - Steel drums with grouted intermediate level ion exchange resin

2.4. **Solid waste treatment**

This section describes the treatment methods for solid waste, both on and off site. There is also a description of the different storage facilities and capacities on site. For further information regarding the continued waste management process, intermediate storage and final recipient see chapter 5.

Radioactive waste generated during D&D intended for final repository is managed in such a way to fit the system for dealing with Swedish radioactive waste, see appendix 2. The Swedish system includes cooperation with SKB and common solutions to meet requirements with respect to waste management, packaging, transport and final repository in SFR and SFL. Since neither SFR for decommissioned waste nor SFL are constructed, it is planned for interim storage of waste on site in the meantime.

2.4.1. Treatment at site

Collecting and sorting

Waste should be sorted, to the greatest possible extent, as close as possible to where it is created or to the decommissioning site. The waste is sorted according to origin, material type and activity. Activity is assessed through characterisation and measurement. Also hazardous waste is characterised in order to be free released in accordance with SSM's regulations for free release. If free release is not possible the waste is disposed in SFR according to agreements with SKB.

Radioactive waste is sorted with regard to waste category and final recipient, see table 2-1.

Table 2-1. Overview waste categories

Category	Surface dose rate [mSv/h]	Planned final recipient
Materials possible to free release.	Not applicable	External recipient
Materials for free release (metals) and combustible material.	< 0,1*	To be used in other industry, external recipient
VLLW	≥ 0,1 - < 0,5	Surface repository, SFR
LLW	≥ 0,5 - < 2	SFR
ILW	> 2	SFR/SFL

*Refers to the requirements of the recipient.

Waste to be exempt, free released
Free release of materials will be performed continuously during D&D. The purpose of free release is to minimise the quantities of radioactive waste that require final disposal. The materials can be free released immediately or after treatment, such as decontamination. If the material cannot be decontaminated it is managed as radioactive waste. BKAB will set up a free release facility on site for free release measurements during D&D.

Handling of Short lived very low level and low level waste (VLLW and LLW)
The waste consists of trash and metal scrap with a surface dose rate <2 mSv/h. The waste is compacted if possible. Waste is placed in a shipping container for interim storage or buffer storage pending transportation to external recipient.

Short lived intermediate level waste (ILW)
Solid waste in the form of garbage and metal scrap with a surface dose rate >2 mSv/h is sorted at the dismantling site and collected into a steel or concrete box.

Handling of segmented Reactor internals and Long-lived low and intermediate level waste (LLW and ILW)
Reactor internals from the reactor pressure vessels have been segmented and packaged into steel tanks. Long-lived low and intermediate level waste trash and scrap metal are packaged into concrete moulds with bolted lids. The waste packages are designed for final disposal at SFL and will initially be placed in interim storage at the Barsebäck NPP. Interim storage at an external site may be possible.

2.4.2. Treatment off site

Smelting
Smelting of metal is a method that can be used in order to achieve a homogenous distribution of activity in materials were different nuclides may not be separated out. Another advantage with smelting is a reduction of the waste volume.

When smelting is feasible, low level metal scrap will be sent to an approved external facility for smelting and free release of the resulting ingots or final disposal if required.

Incineration
During decommissioning low level combustible waste will be created such as plastics, cleaning and personnel protection equipment. Combustible waste is sent to an approved external facility for treatment (incineration). If the criteria for incineration cannot be met the waste is sent for final disposal.

Both smelting and combustion are used to a lesser degree for waste management during C&M operation.

2.4.3. Package

All radioactive material and waste is placed and transported away in approved waste packages, in accordance with the Swedish transport agency’s and the Swedish civil contingencies agency’s regulations [8], [9] and [10] and waste acceptance criteria stipulated for each final recipient.

2.4.4. Storage on site

In order to achieve an efficient a decommissioning logistics process, the flow of waste and waste packages needs to be as unimpeded as possible. Certain decommissioning stages could be more time-consuming than others and in order to maintain a smooth flow there is a need for buffer storage and interim storage facilities. Existing storage together with the proposed new storage space, interim storage 2, are estimated to have sufficient storage capacity based on the plans for the demolition and disposal of the waste. Storage spaces are designed to achieve well-functioning radiation protection for both staff and environment, and are located in controlled areas.

Existing storage

AB- and C-storage

Existing storage in which operational waste in containers such as steel drums and concrete moulds are stored. Operational waste is to be transported to SFR. The aim is to demolish the AB- and C-storage at the same time as the buildings in the power plant area are demolished, but for as long as they remain they will be used as a storage location for the waste logistics at the Barsebäck NPP. The AB-storage refers to short lived intermediate-level waste in steel- or concrete moulds to be stored. In the warehouse there is space for about 1000 boxes. In the C-storage it is possible to store containers with low level waste.

ATB-storage

The ATB-storage is used as a storage location for ATBs (waste transport containers) and shipping containers before transportation to SFR or other recipient. The ATB-storage can also be used for storing equipment that requires protection against the elements. The ATB-storage will remain during decommissioning and dismantling. In the storage there are place for 10 ATBs or about 40 containers.

Interim storage 1

An existing storage facility used today for storing the reactor internals packaged in steel tanks. The reactor internals consist of long-lived waste destined to be disposed of in the repository for long-lived waste, SFL. The interim storage 1 is planned to be used during decommissioning and dismantling for storage of short-lived intermediate level waste stored in, for example, steel- or concrete boxes. The Interim storage 1 is designed for 120 steel tanks. Segmentation of reactor internals is expected to generate about 70 steel tanks. The storage facility will remain in place until the waste can be transported to SFR or SFL or to external interim storage.

Planned storage

A new interim storage facility constructed for decommissioning waste. The storage facility is planned to be built close to the already existing interim storage 1. The interim storage facility is primarily for storing shipping containers loaded with short-lived low level waste. The interim storage can also be used as a location for storing large components and shipping containers with waste that are to be sent to an external recipient. The storage will remain in place until SFR is extended and ready to receive the waste.

The planned new storage facilities will be designed to together with existing storage facilities to have sufficient storage capacity according to the existing plans for the decommissioning and shipping of waste.

Buffer storage

Buffer storage refers to places for temporary storage of waste. Temporary storage of radioactive waste may be required pending continued management of the waste on site or pending transportation to external storage, external surface repository or to external treatment. Identified areas for buffer storages are:

- Areas within the turbine buildings (e.g. turbine halls and pump/preheater halls)
- AB- and C- storage
- ATB-storage
- Area adjacent to where waste management is performed
- Interim storage 2

2.5. Containment

Containment is the term describing the protective measures used at the Barsebäck NPP to contain radioactive substances.

During D&D, as well as during C&M operation, only the outer shell barrier is utilised. Other barriers that were credited during power operations, such as fuel, fuel cladding, primary system and reactor containment, are not applicable during D&D. The outer shell barrier is defined by SSM as “Physical obstacle that directly or indirectly counteracts the distribution of radioactive substances”.

It is normally the building walls that fulfil the outer shell barrier function to prevent external discharge. Not until a discharge reaches outside the building, the barrier is considered breached.

The outer shell barrier function is also provided by tank cells, tanks, piping and containers/waste packages with respect to internal discharges that may affect personnel. Not until these are compromised and personnel risk exposure to radiation, the barriers are considered breached.

In order to clarify the overview of requirements for a facility in D&D, BKAB uses the terms *protective function*, *requirement function* and *requirement system*.

In figure 2-4 the relationships between these terms are shown in order to describe how they ensure that the outer shell barrier is maintained.

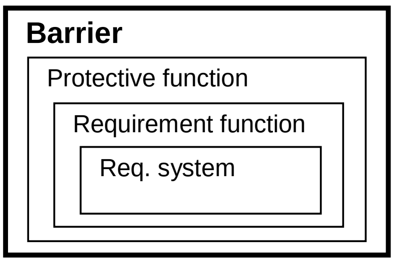


Figure 2-4. Relationship between barrier, protective function and protection system

Protective functions are tasked with maintaining barriers to protect the environment and personnel against the dissemination of activity and include:

- Fire protection
- Protection against unauthorised access
- Protection against flooding
- Monitoring of radioactive discharges

Requirement functions are the system functions required to fulfil a protective function, i.e. acceptance criteria regarding the integrity of the barrier and discharge of radioactivity to the environment and within the plant, which should be applicable for the Barsebäck NPP during D&D in order for the facility to fulfil the requirements for a safe facility. The requirement functions include:

- Radioactive discharge and monitoring
- Waste management
- Firefighting and blowing paths
- Facility security
- Floor drains and drainage paths
- Ventilation and sealing of buildings

Requirement systems' main purpose is to, possibly together with other requirement systems, fulfil a certain requirement function.

Operating systems denotes those system functions with operational assignments that should remain during D&D, including supplying the system functions. Systems with operational assignments include service systems, power supply, control and surveillance.

2.6. Interim storage 2

2.6.1. Main features of the installation

BKAB will build a new building, interim storage 2, for interim storage of primarily short-lived very low level waste (VLLW) and short-lived low level waste (LLW), but other radioactive waste, such as large components, may be stored in the building.

Interim storage 2 is to be constructed in the harbour area, 3,0 m above sea level, close to the existing interim storage 1. Prior to construction, existing goods reception building must be demolished according to applicable requirements. The main purpose of locating the interim storage facilities close to the harbour is to facilitate the logistics during transportation of the waste by boat, as well as to enable the area to be limited when only the interim storage facilities remain at the site.

Interim storage 2 will only be used as a storage space and the capacity will be adapted as required. Applicable building rules shall apply and the following safety principles will apply for the interim storage 2:

– **Prevention of Unauthorised access**
Interim storage 2 will be located within a secured area and provided with security boundaries. All waste packages are therefore stored in a secured area. Transportation is conducted within a secured area at all times. Recorded personal access takes place via a gate at the entrance. Alarms for unauthorised access and unauthorised entry will be connected to the existing security centre.

– **Radioactive discharge**
Interim storage 2 functions as a barrier against accidental discharge to the environment and will provide a sufficient seal to prevent radioactive substances to be discharged to the environment.

– **Radiation protection**
Interim storage 2 will be constructed in such a way that the surface dose rate on the outside of the building will be <2 μSv/h.

– **Fire protection**
Interim storage 2 will fulfil applicable fire regulations and requirements.

2.6.2. Ventilation systems and the treatment of gaseous and airborne waste

As no radioactive discharges are expected from interim storage 2, the building will be designed without (forced) ventilation and without permanent air sampling for activity monitoring [11].

2.6.3. Liquid waste treatment

The interim storage 2 will have no waterfilled process lines or sprinklers. There will be no systems for industrial water or waste water in the building. The waste will not contain any liquids.

Hence there is no need for any liquid waste treatment in interim storage 2.

2.6.4. Solid waste treatment

No treatment of the waste will be performed in interim storage 2.

2.6.5. Containment

The building will provide shielding so that the dose rate outside the exterior walls will not exceed 2 μSv/h. The interim storage 2 will not result in any contribution of radiation dose to any individual in the reference group.

2.6.6. Decommissioning and dismantling

Interim storage 2 will remain in the harbour area until all radiological waste has been transported to the final repository.

The interim storage 2 will be dismantled after the radiological waste has been removed. It is expected that the building will fulfil the criteria for free release and then conventionally demolished when necessary permits have been granted due to that only solid waste in containers and larger components have been stored in the building and that there is no process water within the building.

The dismantling of interim storage 2 will follow the guidelines and regulations that apply to the demolition of the rest of the Barsebäck NPP.

3. Release from the installation of airborne radioactive effluents under normal conditions

This chapter mainly discusses the discharges to air. However, some information is valid for both air and water discharges, such as the authorization procedure in force, section 3.1, origins of the radioactive effluents in section 3.2.1 and evaluation of transfer to man, section 3.4.

Sections 3.1 - 3.4 are arranged in accordance with the requirements in Annex III (2010/635/Euratom), thus applicable to the existing plant to be decommissioned.

Section 3.5 is arranged in accordance with the requirements in Annex II (2010/635/Euratom), thus applicable to the interim storage 2 to be constructed.

All information presented regarding activity, doses and other radiological analyses are based on the fact that all internal parts from the reactor pressure vessels are stored in the interim storage 1 during D&D and applies both to normal conditions as wells as unplanned discharge of radioactive effluents.

3.1. Authorisation procedure in force

Compliance with requirements that apply during C&M operation is demonstrated by defining reference and target values for the discharges to air. These historical values for discharges of activity to air have generally been much below the dose limit of 0,1 mSv/year to the representative individual.

3.1.1. Legislation on nuclear activities

The Act on Nuclear Activities (1984:3), the Radiation Protection Act (2018:396) and Radiation Protection Ordinance (2018:506) with instructions for the Swedish Radiation Safety Authority together with the Ordinance on Nuclear Activities (1984:14), stipulate the boundaries for all nuclear activities in Sweden. SSM has developed regulations (SSMFS) to provide a more detailed framework for e.g. nuclear power plants. Some of the acts, ordinances and regulations are available in English.

SSM oversees that nuclear operations are conducted safely by issuing regulations as well as carrying out follow-ups, inspections 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 chapter 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 2018:1 The Swedish Radiation Safety Authority’s regulations concerning basic provisions applying to licensed activities involving ionizing radiation (not verbatim translation)

Radioactive releases from nuclear facilities that are being dismantled and demolished are not regulated by SSMFS 2008:23. Instead the requirements in the specific licence conditions for decommissioning [12] issued by SSM are to be followed.

3.1.2. Discharge limits and associated requirements for decommissioning

SSM has issued licence conditions for decommissioning related to radioactive releases from facilities that are being decommissioned [12]. The conditions include the handling of discharges and waste during D&D.

In Sweden discharge limits are not specified explicitly in terms of activity [Bq]. The limits are specified instead as the annual dose to a representative individual living in the village of Barsebäck Harbour, in the vicinity of the Barsebäck NPP. The annual dose must not exceed 0,1 mSv according to the licence conditions for decommissioning [12] and SSMFS 2018:1. The dose limit is specified as the sum of doses received from discharges to air and to water. The discharges are reported in activity [Bq] as well as in dose [mSv]. The focus for reducing the discharges is on activity. For each reactor, reference and target values shall also be determined. The annual dose from emissions shall be optimized according to the principle of BAT. The dose 0,1 mSv/year is the formal dose restriction limit.

The reference value for a nuclide, or a group of nuclides, is the normal optimised discharge level that is possible to reach during 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 reduce the activity discharges in the short and long term perspective.

The reference values and target values for the Barsebäck NPP are specified for the discharges to air from each unit. The discharge to water is specified as one reference value and one target value, as the units have one common system for processing the liquid discharges

Reference values and target values are all defined for Co-60. This nuclide has a major effect on the dose to the reference group. A summary and a validation of the past year's outcome on discharges and the forthcoming reference and target values for next three years is reported to the SSM [13]. The reference and target values for a three-year period are then approved by SSM.

B1 was permanently shut down in 1999 and B2 in 2005. During the late 1990s the BAT concept was also implemented, as a result the discharges to air, and especially to water, have shown decreasing trends.

Figure 3-1 shows the historical outcome of the emissions of C-60 to air for the Barsebäck NPP. The values indicated with the red line represent reference values for the time period 2002 – 2018 and target values for the years 2019 and 2020.

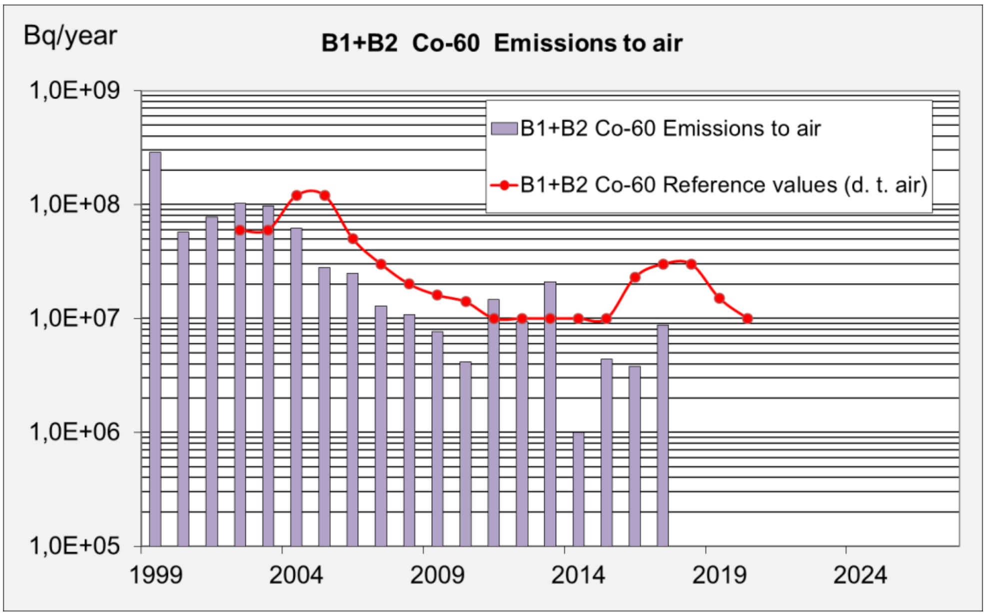


Figure 3-1. Emissions of Co-60 to air from B1 and B2. The values indicated with the red line represent reference values for the time period 2002 – 2018 and target values for the years 2019 and 2020.

The reference value for 2018 and the target values for the period 2019 to 2020 are shown in table 3-1.

Table 3-1. Reference and target values for Unit B1 and Unit B2 for 2018 to 2020 [13].

	Ref. value 2018 Co-60 [Bq]	**Target value 2019 Co-60 [Bq]**	**Target value 2020 Co-60 [Bq]**
B1 Emissions to air	1,5E+07	1,0E+07	5,0E+06
B2 Emissions to air	1,5E+07	5,0E+06	5,0E+06
B1+B2 Emissions to air	3,0E+07	1,5E+07	1,0E+07
B1+B2 Discharges to water	2,0E+08	1,0E+08	1,0E+08

3.1.3. Environmental impact assessment

The environmental assessment procedure follows the required steps stipulated in the Swedish Environmental Code. In order to provide a high level of protection to the environment and reduce the environmental impact, all environmentally hazardous activities and operations are required to apply for a licence in accordance with the Environmental Code.

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 description of the plant or activity as well as descriptions of the technology that will be used, considering the best available technology (BAT). Analysis of different alternatives for both these aspects is 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 SSM are also consulted in the licensing procedure and are given the opportunity to propose conditions.

In July 2011 BKAB applied for a licence for C&M operation and partial dismantling of the Barsebäck NPP including construction of interim storage 1 for storage of radioactive waste. This licence was issued in December 2012. BKAB also has two older court rulings valid for water operations issued by the Swedish Water Court.

The process of applying for a new licence for D&D commenced with the public consultation in February 2018.

3.2. Technical aspects

SSM requires that discharges shall be reported according to SSMFS 2018:1 and the licence conditions for decommissioning [12].

BKAB were granted an exemption from SSM [6] to discontinue the measurement noble gases and the continuous sampling and measurement iodine once the fissile material was removed. This exemption also comprises measurements of H-3 to air and C-14 to air and water.

The focus in this report will be on Co-60, which is the most important nuclide in the aerosol discharges to air. In 2017 the nuclide comprised 75 % and 98 % for B1 and B2 respectively of the total dose from discharges to air. Aerosols are collected using aerosol filters and analysed with respect to gamma-emitting nuclides. Alpha-emitting nuclides (Pu-238, Pu-239/240, Am-241, and Cm-242 and Cm-244) and Sr-90 are also measured on the aerosol filters on a 6-month basis.

Discharges to air at normal conditions during dismantling of contaminated systems/buildings will be affected according to the decommissioning sequence for the Barsebäck NPP.

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

B1 and B2 are two 2nd generation Asea Atom-built boiling water reactors with external main circulation loops. They are identical in design and also in the way they were operating during power production. Both units were power uprated by 6 % in 1986. Both units have had very low frequencies of fuel failures. A failure occurred only once, at B2 in 1988, causing a minor release of actinides.

Both units had very low moisture content in the high-pressure steam, resulting in only low levels of contamination of the turbine system. On the low-pressure turbine system and turbine condenser of B1, the contamination is estimated to be near free release levels.

All fuel elements and core neutron detectors were sent to Clab in 2006. All control rods were sent to Clab in 2011.

Major chemical system decontaminations were performed at both units (B1/2008, B2/2007). The systems that were decontaminated were the main circulation loops, the residual heat removal system, the reactor cleaning system, the scram system, the radioactive part of the feed water system, the bottom calotte of the reactor pressure vessel and the reactor drainage system. Decontamination factors of 100 – 200 were achieved.

Segmentation of reactor internals is underway (2016-2019), and stored in the interim storage 1.

The remaining intermediate level radioactive operational waste in the form of spent filters and resin is approximately 5 m^3. It is stored in storage tanks in the liquid waste facility and will be processed in 2019 to 2020.

Activated corrosion products

Both units have cobalt-containing valves (Stellite®) installed, which were the dominant source for dose build-up of the most important of activated corrosion products, Co-60, on pipes, heat exchangers, etc.

Carbon steel contributes to the production of relatively short-lived Mn-54 and iron isotopes such as Fe-59 and Fe-55. Stainless steel also contributes to the production of short-lived Cr-51, Co-58 and beta-emitters such as Ni-59 and Ni-63.

The turbine condenser tubes were changed from brass (zinc and copper) to titanium in 1982-1983. This means that the only significant sources for Zn-65 and Co-60 are not present at the time of decommissioning. During 2002 to 2005 the Unit 2 practiced injection of DZO, “Depleted Zinc (Zn-64) Oxide”, to feed water as a method to inhibit the deposit of Co-60 to the system surfaces. The use of DZO had the effect that the production of Zn-65 was minimised.

Silver and antimony are two metals that have nuclei with high cross-section for neutron activation resulting in the production of problematic activation products such as Ag-108, Ag-110m, Sb-124 and Sb-125. The Barsebäck NPP has had no significant problems with these nuclides as silver and antimony-containing materials have successfully been avoided in the replacement of bearings, seals and other components, which constitutes a possible source for contamination from these metals.

Via corrosion of the construction materials the metals are carried with system water to the core where they deposit. During the residence time on the core surface the metals are activated and then partly released once again to the water as activated corrosion products which subsequently deposit as particles and as ions on system surfaces of the primary systems. Some of the activated corrosion products are transported by steam moisture to the turbine. Activation products are also collected by filters in reactor water and turbine water polishing resins. A minor proportion of the corrosion products are released as discharges to air and to water.

Induced activity in materials

The components that are subjected to direct neutron activation are:

– Reactor Pressure Vessel (RPV) – carbon steel and stainless steel.

The nuclides produced are in general the same as the activation products. In addition to the activated corrosion products, induced metal also contains C-14.

– Reactor internals – stainless steel and nickel based alloys.

The nuclides produced are in general the same as the activation products. Reactor internals were/are being segmented in 2016-2019, and stored in the interim storage 1

– Fuel box – stainless steel and zirconium material.

The majority of fuel boxes left the plant in 2006 when they were transported to Clab as a combined part of the fuel elements. A minor number of fuel boxes remained onsite. In 2017 the remaining fuel boxes were combined with the segmented reactor internals and placed in interim storage 1.

– Control Rods – stainless steel, boron carbide (B4C), Hafnium (Hf)

The activation products in stainless steel are the same as in activated corrosion products plus C-14. B4C generates H-3. Activation of Hf generates no significant long-lived radionuclide of importance.

All control rods were sent to Clab in 2011. The control rods at B1 and B2 had no significant leakage of H-3. The inventory of H-3 in pool water has been governed by activation of water and the relatively high turnover of water at the units. When the decommissioning starts the pools will be drained and there will only be an insignificant inventory of water bound H-3 remaining in the liquid waste facility.

– Biological shield – concrete.

Activated concrete contains Ca-41, Eu-152, Eu-154 and Cs-134.

– RPV isolation - aluminium and asbestos.

Isolation outside the RPV contains neutron-activated products from trace metals.

Non-metallic activation products

Non-metallic activation products that can be of radiological importance are the following:

C-14	– in induced material and in ion exchange resins as carbonate ion.
H-3	– in induced material and in water.
Cl-36	– in induced material and in ion exchange resins as chloride ion (Mainly a nuclide to consider in the SAR for the long term waste storage at SFL and SFR.)

Fission products

Fission products to consider are:

Cs-137	– in ion exchange resins and in sand tank for off gases.
Cs-134	– in ion exchange resins.
Sr-90	– in ion exchange resins and in sand tank for off gases.

Actinides

The contamination from Pu-238, Pu-239/240, Pu-241, Am-241, Cm-244 and Cm-242 originate primarily from fuel failures which have developed to secondary fuel failures. Secondary fuel failures mean that water comes in contact with the uranium and dissolves the fuel matrix. The uranium and its activation products, of which many are alpha-emitting nuclides, are by this process spread mainly to the core surfaces and to the reactor water cleaning system. A minor fraction deposits on the hot system surfaces as an integrated part of the oxide layer together with metallic activated corrosion products. Most of these actinides on system surfaces were relocated to spent ion exchange resin during the chemical system decontamination of the units.

Another source of actinides can arise if used neutron monitors, containing small amounts of highly enriched U-235, are damaged during the decommissioning process. This was the case at B1 and B2 in 2006 when neutron detectors were segmented in pools which resulted in an emission of actinides to the pool water. The pool water was filtered and the actinides released from the neutron monitors were collected on ion exchange resins.

Models and measurements for radioactive inventory

The radioactive inventory of the Barsebäck NPP has been defined for the reference date 2019-01-01[14]. Measurement and models for this calculation can primarily be divided into two parts:

A. Model calculations for induced activity in reactor internals, RPV, and biological shield.
The codes used are Origen [15] for the fuel neutron spectra, MCNP [16] as the neutron transport code, and FISPACT [17], [18] and [19] for the activation of the materials. The code calculations were based on detailed input data on power history, peripheral bundles power history, drawings/geometries and material composition.

B. Model calculations for oxide-bound surface activity ("crud").
The codes used are BwrCrudAct and BwrCoolAct, [20]. The codes use compartment analysis for metal- and radioactivity at steady state during power operation. The data have been benchmarked with plant-specific (B1 and B2) measured chemical analyses and nuclide-specific analyses on fuel deposits, reactor water, pipe surface activity, chemical decontamination results and dose rates.
Also, from the BwrCrudAct it is also possible to calculate the activity that is accumulated in the ion exchange resins.

Radioactive inventory

The radioactive inventory for the entire plant has been calculated for the reference date 2019-01-01 and table 3-2 summarises the activity inventory in the buildings at Units B1, B2 [14] and contaminated soil on the site. The total activity in B1 and B2 is 3,3E15 Bq. Contaminated soil is the sediment in two sediment ponds. The amount of Co60 in these ponds is estimated to 5 E8 Bq. See table 3-2.

Table 3-2. Total activity in buildings at Units B1 and B2 [14] (Ref. dat. 2019-01-01).

	Building									**B1+B2**
	B1 Reactor [Bq]	**B1 Turbine [Bq]**	**Liquid Waste facility [Bq]**	**(ABC) Solid Waste Storage [Bq]**	**Service [Bq]**	**Interim storage 1 (Internals) [Bq]**	**B2 Reactor Building [Bq]**	**B2 Turbine [Bq]**	**Soil [Bq]**	**Total [Bq]**
H-3	9,7E+11		6,2E+05	2,0E+07		1,7E+11	1,2E+12			2,4E+12
Be-10	4,8E+02		2,1E-02	6,8E-01		5,8E+03	5,1E+02			6,7E+03
C-14	9,8E+08	2,3E+07	7,2E+08	4,0E+08	6,3E+06	3,4E+12	1,4E+09	2,7E+07		3,4E+12
Cl-36	1,7E+07	2,7E+02	5,8E+05	4,9E+05	1,4E+03	9,5E+08	1,8E+07	3,2E+02		9,9E+08
Ca-41	1,5E+09		3,2E-11	1,0E-09		8,8E-06	1,5E+09			3,0E+09
Fe-55	1,6E+11	3,7E+08	6,2E+10	2,3E+11	3,9E+07	5,3E+14	6,1E+11	7,3E+08		5,3E+14
Co-60	2,7E+11	1,1E+10	4,1E+11	1,0E+12	8,1E+08	5,2E+14	5,1E+11	3,7E+09	4,7E+08	5,2E+14
Ni-59	3,2E+09	4,0E+07	2,0E+09	7,4E+09	3,8E+06	2,1E+13	3,9E+09	1,5E+07		2,1E+13
Ni-63	3,3E+11	4,8E+09	2,2E+11	8,5E+11	4,3E+08	2,2E+15	4,2E+11	1,9E+09		2,2E+15
Se-79	4,9E+02	2,5E-01	1,2E+03	2,9E+00	5,6E+00	8,2E+02	5,2E+02	1,3E-01		3,1E+03
Sr-90	5,5E+07	1,3E+08	5,2E+09	5,7E+08	3,1E+06	4,5E+09	1,9E+08	2,0E+08	1,6E+07	1,1E+10
Zr-93	2,4E+07	4,0E+05	3,0E+06	1,5E+08	1,2E+04	1,2E+10	2,7E+07	3,9E+05		1,3E+10
Nb-93m	4,7E+10	8,3E+08	2,0E+11	3,5E+11	6,0E+08	6,3E+12	9,6E+10	1,4E+09		7,0E+12
Nb-94	1,2E+08	1,7E+06	6,1E+08	7,1E+08	1,7E+06	1,8E+11	1,9E+08	2,5E+06		1,8E+11
Mo-93	2,5E+08	4,0E+04	1,2E+07	5,7E+07	2,7E+04	3,8E+11	2,7E+08	3,9E+04		3,8E+11
Tc-99	1,4E+07	8,2E+03	1,8E+07	4,8E+06	8,2E+04	2,2E+10	1,6E+07	7,2E+03		2,2E+10
Ru-106	8,4E+02	1,4E+01	1,9E+05	2,2E+04	5,4E+03	1,3E+05	4,4E+04	1,2E+02		3,9E+05
Ag-108m	4,3E+08	2,5E+06	2,2E+08	9,0E+08	6,4E+05	6,6E+09	4,7E+08	2,6E+06		8,6E+09
Pd-107	1,7E+01	3,6E-01	1,8E+03	4,1E+00	8,1E+00	3,0E-04	3,5E+01	1,9E-01		1,9E+03
Cd-113m	8,9E+05	3,1E-01	1,8E+03	6,8E+02	8,7E+00	5,7E+06	1,1E+06	2,1E-01		7,7E+06
Sn-126	6,7E+02	1,4E+01	8,9E+03	7,6E+03	4,0E+01	6,9E+04	2,3E+03	3,2E+01		8,9E+04
Sb-125	6,3E+08	1,3E+07	2,9E+09	8,0E+09	2,1E+06	1,6E+12	2,6E+09	3,7E+07		1,7E+12
I-129	1,4E+03	2,5E+02	1,9E+05	1,2E+05	2,3E+02	3,7E-03	2,8E+03	7,6E+02		3,1E+05
Cs-134	2,6E+07	6,6E+01	7,2E+07	1,7E+07	4,3E+05		1,4E+08	1,3E+02		2,6E+08
Cs-135	1,0E+04	4,1E+04	2,2E+06	1,4E+06	2,6E+03		1,7E+04	9,0E+04		3,7E+06
Cs-137	6,3E+09	2,1E+09	1,2E+11	8,1E+10	2,2E+08		2,0E+09	1,6E+09	1,6E+09	2,2E+11
Ba-133	8,5E+07	2,2E-02	1,3E+02	7,5E+01	6,5E-01		1,1E+08	1,6E-02		2,0E+08
Pm-147	4,6E+06	7,0E+03	4,4E+06	6,2E+06	4,4E+04	4,2E+07	1,9E+07	3,5E+04		7,6E+07
Sm-151	3,3E+09	7,2E+03	6,5E+06	4,0E+06	2,1E+04	2,8E+07	3,5E+09	1,7E+04		6,9E+09
Eu-152	7,2E+10	4,6E+01	3,4E+04	2,1E+05	1,5E+02	1,8E+05	9,1E+10	1,2E+02		1,6E+11
Eu-154	2,2E+09	1,4E+04	1,5E+07	8,7E+06	5,3E+04	6,0E+07	3,2E+09	4,2E+04		5,6E+09
Eu-155	3,4E+08	1,5E+03	1,7E+06	1,0E+06	6,6E+03	6,9E+06	6,9E+08	5,3E+03		1,0E+09
Ho-166m	3,5E+07	8,8E-02	5,7E+01	4,9E+01	2,5E-01	3,5E+02	3,6E+07	2,0E-01		7,2E+07
U-232	7,5E+00	1,6E-01	7,6E+01	9,7E+02	1,6E-01	7,4E+06	2,8E+01	4,0E-01		7,4E+06
U-236	3,2E+02	6,8E+00	2,0E+03	4,0E+03	6,5E+00	3,2E+04	1,2E+03	1,7E+01		4,0E+04
Np-237	3,1E+02	6,6E+00	1,1E+04	9,9E+03	6,3E+00	3,9E+04	1,1E+03	1,6E+01		6,2E+04
Pu-238	9,3E+10	5,7E+05	8,9E+07	7,6E+07	7,0E+04	3,0E+08	8,4E+06	1,2E+05	1,1E+05	9,3E+10
Pu-239	1,4E+06	3,7E+04	3,1E+06	4,6E+06	1,5E+04	2,1E+08	2,3E+06	1,7E+04		2,2E+08
Pu-240	5,7E+05	6,0E+04	4,6E+06	7,5E+06	2,2E+04	1,7E+08	2,1E+06	2,9E+04		1,9E+08
Pu-241	2,6E+07	3,2E+06	1,7E+08	3,3E+08	6,3E+05	2,7E+10	1,1E+08	1,6E+06		2,8E+10
Pu-242	2,3E+03	2,0E+02	8,3E+03	2,4E+04	4,6E+01	5,5E+05	8,4E+03	1,2E+02		5,9E+05
Am-241	3,7E+06	1,3E+05	1,1E+07	1,7E+07	2,9E+04	1,2E+09	4,4E+06	6,2E+04		1,3E+09
Am-242m	7,8E+03	6,9E+02	2,8E+04	8,1E+04	1,6E+02	2,0E+06	2,9E+04	4,1E+02		2,2E+06
Am-243	2,5E+04	2,3E+03	1,1E+05	2,7E+05	5,1E+02	4,7E+06	9,3E+04	1,3E+03		5,2E+06
Cm-243	8,5E+03	8,0E+02	2,9E+04	9,8E+04	1,9E+02	8,5E+07	3,4E+04	4,8E+02		8,5E+07
Cm-244	1,1E+06	1,3E+05	7,6E+06	1,4E+07	2,6E+04	1,1E+08	4,9E+06	6,9E+04		1,4E+08
Cm-245	2,8E+02	2,5E+01	1,0E+03	2,9E+03	5,6E+00	4,3E+04	1,0E+03	1,4E+01		4,9E+04
Cm-246	8,5E+01	7,5E+00	3,1E+02	9,0E+02	1,7E+00	9,6E+03	3,1E+02	4,5E+00		1,1E+04
Total	**2,0E+12**	**1,9E+10**	**1,0E+12**	**2,6E+12**	**2,1E+09**	**3,3E+15**	**3,0E+12**	**9,5E+09**	**2,1E+09**	**3,3E+15**

3.2.2. Annual discharges expected during dismantling and demolition

The historical radioactive emission to air can in most cases be explained by activities such as solidification of ion exchange resins or work in the reactor halls. The basis for a prognosis of the anticipated radioactive emissions during decommissioning is good knowledge of these activities. Examples of such activities are:

1. High pressure washing of contaminated surfaces.
2. Filter cleaning.
3. Dry up of contaminated surfaces, pool walls etc.
4. High concentration of dissolved and suspended activity in pool water.
5. Pool cleaning.
6. Drilling, cutting and decommissioning in general of RPV, pipes, tanks, filters, biological shield and other contaminated components.
7. Ventilation, venting and drying of components.
8. Mixing ion exchange and water resin by air intrusion in tanks and pipes.
9. High pressure compacting.
10. Decontamination activities in general.

During decommissioning it is likely that no. 1, 3, 5, 6, 7, 8, 9 and 10 of the above listed activities will occur.

The method of decommissioning the plant and the precautions taken to prevent the spread of radioactivity will have a strong impact on the amount of radioactivity that can be emitted to air.

The prognosis of radioactive emissions to air during decommissioning is based on the knowledge of the plant history on emissions, the corresponding activities and the effect of prevention made to reduce the emissions.

In order to estimate the radioactive emissions to air (and water) during decommissioning, data from the year 2017 [21], corrected for decay, were used [22].

Normally the nuclide Co-60 is the dominating nuclide for both emissions to air and to water. However, during 2017 Cs-137 was the dominating nuclide for emissions to water. As the measured nuclide vectors for 2017 are used for prognosis during D&D, Cs-137 will also be the dominating nuclide for emissions to water in the future. Co-60 is still used as the reference nuclide for emissions to both air and to water

A prognosis of the activity emissions to air has been performed for the period 2020 – 2027, which is the timeframe as set out in the current decommissioning plan, see tables 3-3, 3-4 and 3-5. The B1 and B2 nuclide vectors have been restricted to the nuclides that are likely to exceed detection limits and also have a significant impact to the dose to the reference group, the most exposed part of the population residing near the NPP.

Table 3-3. Prognosis of activity emissions to air from B1 during decommissioning [22].

	Air B1 [Bq] 2020	**Air B1 [Bq] 2021**	**Air B1 [Bq] 2022**	**Air B1 [Bq] 2023**	**Air B1 [Bq] 2024**	**Air B1 [Bq] 2025**	**Air B1 [Bq] 2026**	**Air B1 [Bq] 2027**
Co-60	5,8E+06	8,3E+06	6,4E+06	9,4E+06	5,3E+06	4,8E+06	3,6E+06	5,0E+06
Cs-137	6,5E+04	1,0E+05	9,0E+04	1,5E+05	9,1E+04	9,2E+04	7,8E+04	1,2E+05
Sb-125	-	-	-	-	-	-	-	-
H-3	-	-	-	-	-	-	-	-
Sr-90	3,3E+05	5,3E+05	4,6E+05	7,5E+05	4,6E+05	4,7E+05	3,9E+05	6,1E+05
Pu-238	3,5E+03	5,7E+03	5,0E+03	8,3E+03	5,3E+03	5,4E+03	4,6E+03	7,3E+03
Pu-239/Pu-240	2,0E+03	3,2E+03	2,9E+03	4,8E+03	3,0E+03	3,2E+03	2,7E+03	4,3E+03
Am-241	4,6E+03	7,4E+03	6,6E+03	1,1E+04	7,0E+03	7,2E+03	6,2E+03	9,9E+03
Cm-244	-	-	-	-	-	-	-	-

Table 3-4. Prognosis of activity emissions to air from B2 during decommissioning [22]

	Air B2 [Bq] 2020	**Air B2 [Bq] 2021**	**Air B2 [Bq] 2022**	**Air B2 [Bq] 2023**	**Air B2 [Bq] 2024**	**Air B2 [Bq] 2025**	**Air B2 [Bq] 2026**	**Air B2 [Bq] 2027**
Co-60	1,6E+07	7,5E+06	1,5E+07	5,7E+06	5,7E+06	4,3E+06	3,6E+06	3,1E+06
Cs-137	3,2E+04	1,7E+04	3,8E+04	1,6E+04	1,8E+04	1,5E+04	1,4E+04	1,3E+04
Sb-125	-	-	-	-	-	-	-	-
H-3	-	-	-	-	-	-	-	-
Sr-90	1,6E+05	8,7E+04	1,9E+05	8,2E+04	9,0E+04	7,5E+04	7,0E+04	6,7E+04
Pu-238	4,7E+03	2,6E+03	5,7E+03	2,5E+03	2,8E+03	2,4E+03	2,2E+03	2,2E+03
Pu-239/Pu-240	1,0E+03	5,7E+02	1,3E+03	5,6E+02	6,4E+02	5,4E+02	5,2E+02	5,1E+02
Am-241	3,9E+03	2,1E+03	4,8E+03	2,1E+03	2,4E+03	2,0E+03	1,9E+03	1,9E+03
Cm-244	-	-	-	-	-	-	-	-

Table 3-5. Prognosis of activity emissions to air from B1+B2 during decommissioning [22].

	Air B1+B2 [Bq] 2020	**Air B1+B2 [Bq] 2021**	**Air B1+B2 [Bq] 2022**	**Air B1+B2 [Bq] 2023**	**Air B1+B2 [Bq] 2024**	**Air B1+B2 [Bq] 2025**	**Air B1+B2 [Bq] 2026**	**Air B1+B2 [Bq] 2027**
Co-60	2,1E+07	1,6E+07	2,1E+07	1,5E+07	1,1E+07	9,0E+06	7,2E+06	8,1E+06
Cs-137	9,7E+04	1,2E+05	1,3E+05	1,6E+05	1,1E+05	1,1E+05	9,2E+04	1,3E+05
Sb-125	-	-	-	-	-	-	-	-
H-3	-	-	-	-	-	-	-	-
Sr-90	4,9E+05	6,1E+05	6,5E+05	8,3E+05	5,5E+05	5,4E+05	4,6E+05	6,8E+05
Pu-238	8,2E+03	8,3E+03	1,1E+04	1,1E+04	8,1E+03	7,8E+03	6,9E+03	9,5E+03
Pu-239/Pu-240	3,0E+03	3,8E+03	4,1E+03	5,4E+03	3,7E+03	3,7E+03	3,2E+03	4,8E+03
Am-241	8,5E+03	9,6E+03	1,1E+04	1,3E+04	9,4E+03	9,3E+03	8,2E+03	1,2E+04
Cm-244	-	-	-	-	-	-	-	-

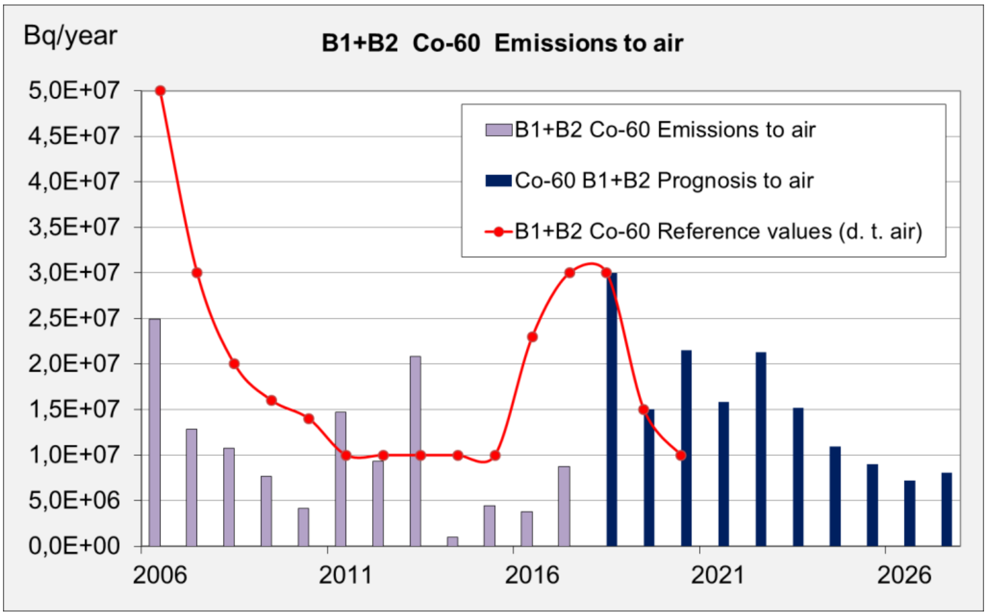


Figure 3-2. Reference values, emissions and prognosis of Co-60 to air from B1 and B2 [22].

Figure 3-2 shows the reference values, the emissions and the prognosis of Co-60 to air from B1 and B2. The prognosis values are associated with the decommissioning sequence and a general decrease in emissions to air is expected from 2020 and forward.

3.2.3. Management of the effluents, methods and paths of release

During power operation and during C&M operation, experience has been developed to reduce activity emissions, both to air and especially to water. The introduction of target and reference values has increased the understanding of continuous improvements, which has resulted in reducing already very low activity emissions to even lower values. Comparisons with other Swedish NPPs have also inspired reductions. The ambition to reduce the activity levels will continue during D&D.

The basis for maintaining low emissions to air is primarily to prevent the generation of airborne activity. The ambition co-operates with the ambition to reduce the generation of other non-radioactive air contamination. Tools for this are the appropriate remediation of the systems before, for example, cutting begins. Another method is the use of point air extraction combined with filters during cutting. The choice of method should take into account the risk of spreading airborne activity. When performing operations where airborne activity may occur, sampling should be performed on the air with low set alarm limits to detect airborne contamination early on.

Today, BKAB has filters installed for cleaning air from the B2 Service Building 1, (2-742 C106 / C107). The previous filter banks (341 C1) used for filtration of ventilation air from the reactor building during normal operation and under accident conditions (341 C2, C3 and C4) have been taken out of service. This means that if airborne contamination occurs during D&D, the spread needs to be limited by using mobile air filters and controlled ventilation flow direction. Installation of local filters on existing nozzles of the room ventilation drums should also be considered.

Work places with expected air contamination can be isolated with tents. Controlled ventilation combined with air filter can be used. Objects such as tanks and the inside of larger components (example turbine condenser) can easily be provided with controlled ventilation and filters [22].

3.3. Monitoring of discharges

3.3.1. Sampling, measurement and analysis of discharges

B1 and B2 have a common laboratory within the controlled area where chemical and radiochemical analyses are performed and a common laboratory in a non-controlled area where environmental surveillance analyses are performed.

Sampling of aerosols is carried out continuously and the filters are changed once a week in the system for activity surveillance in the main stack. The designs of the system are the same in B1 and B2, and follow

ANSI N13.1 - 1969 standard [23]. The system consists of a sampling device in the main stack with nozzles to ensure an average of the air flow. Two redundant fans in a primary loop suck the air from the main stack and transport the air back to the main stack again. Two redundant secondary loops are connected to the primary loop and transport the air at a lower volume flow through parallel loops for sampling of aerosols. (Both primary and secondary loops are redundant and the sampling is changed from one loop to the other once a month.) The flows are automatically chosen to achieve isokinetic conditions, which is a prerequisite for representative sampling. The schematic description of the system is shown in figure 3-3.

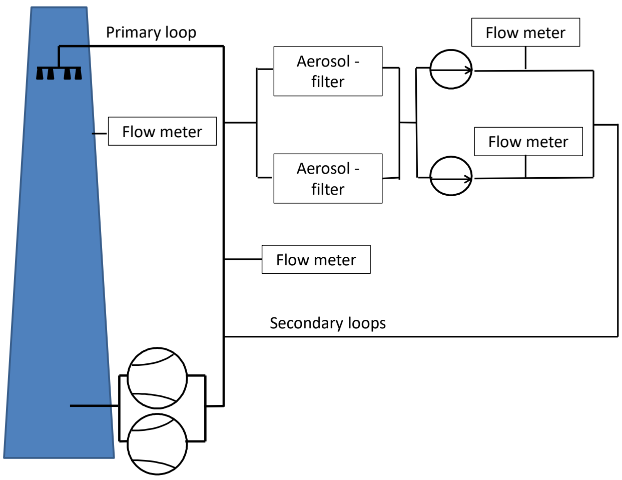


Figure 3-3. Schematic overview of the activity monitoring system in the main stack at B1 and B2.

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, comparative measurements with SSM on aerosol filters are done on a regular basis.

3.3.2. Principal features of the monitoring equipment

Aerosols will be sampled and analysed during D&D. Figures 3-4 and 3-5 show the system for aerosol sampling. The collection of aerosols is continuous and the filters are replaced weekly. Based on the total volume that has passed through the filter, the average air flow in the main stack and the measured activity content in the filter, it is possible to calculate the emissions of aerosols to air.

Figure 3-4. Aerosol sampling at B2 in the activity monitoring system. The pumps in secondary loops and cartridge holder cells are shown. The system at B1 has a similar design.

Figure 3-5. Aerosol sampling at B2: the activity monitoring system. Shows pumps in primary loops and flow regulating valves. The system at B1 has a similar design.

Figure 3-6. Aerosol filter used for activity monitoring in the main stacks at B1 and B2.

The filters, see figure 3-6, are analysed taking nuclide-specific gamma measurements using High Purity Germanium (HPGe) detectors at the local laboratory. Decay corrections are performed for decay during the sampling time. The filters are also used for analyses of Sr-90 and alpha-emitting nuclides with an analysis frequency of every six months.

The aerosol sampling is adjusted for losses during collection, by a conservative factor of 3 set by SSM [24].

There is also mobile equipment dedicated for continuous air monitoring and available for specific tasks during D&D. 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 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 nuclide-specific gamma radiation as well as total alpha at the local laboratory.

3.3.3. Alarm levels and intervention actions

There are automatic alarms connected to the control room for:

- Low airflow alarm in the main stack.
- Low flow alarm in the sampling loops.
- Dose rate alarm on the roof GM-detectors in reactor hall (system 554, 10 μGy/h and 40 μGy/h respectively).

The practice is that when activities take place that (possibly) can have a potential to cause emission to air, radiation protection personnel apply manual air monitoring at that location. These personnel safety measurements can therefore also be used as action levels for risk of exceeding the reference values on emissions. In addition, the sample aerosol filters that are normally changed once a week can also be changed once a day instead, in order to detect an increased emission rate at an early stage.

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/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 [1].

The doses to the reference group in the vicinity of the plant during the D&D phase are shown in figure 3-14 (emissions to air), figure 4-3 (discharges to water) and figure 4-4 (total discharge).

The doses to the reference group (via air, via water and via the sum of air and water) are well below the specified dose limit of 0,01 mSv/year set by the European Commission. 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 emissions [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 [mSv/Bq]. The current dose factors have been used since 2002. The dose factors can be used for both power operations and decommissioning. The dose factors are nuclide and age-specific and calculated for the following four emission points:

- To air from B1 main stack, 113 m above sea level.
- To air from B2 main stack, 113 m above sea level.
- To air from B2 service building 1, stack, 11 m above sea level.
- To water from the common emission point for B1 and B2.

The dose factors have been derived by integrating over a period of 50 years. The dose factors are reactor and height-specific, i.e. the dose factors for emissions to air for B1 and B2 main stack and service building 1 are not the same, mainly due to different stack heights.

Assumptions, calculations and data used for the model are specified in a series of reports [25] - [31].

At present, a review of the dose factors is underway in Sweden. New dose factors will possibly be used from 2019 in all Swedish nuclear power plants, but in this report the Studsvik method from 2002 and its dose factors are applied as those are currently approved. The differences in dose factors between the present and the future models will be 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

The most important site-specific data are given in table 3-6.

Table 3-6. Site-specific data used in the models.

Site specific data	
Sea average depth [m]	12
Height of main stack B1 [m]	113
Height of main stack B2 [m]	113
Height of other air emission points B2 [m]	20
Annual precipitation [mm/year]	645
Average precipitation intensity [mm/h]	0,6
Water outflow [$m^3/(m^2*year)$]	0,25
Part of the year with pasturage [%]	55
Home protection factor from ground radiation	0,18
Global radiation [W/m^2]	143
Average temperature during plant-growing season [°C]	13,0
Plant-growing season length [days]	200
Annual production of grain [kg/m^2]	0,60
Annual production of fodder grain [kg/m^2]	0,54
Annual production of pasture ground [kg/m^2]	0,43
Annual production of vegetables [kg/m^2]	2,9
Annual production of root vegetables [kg/m^2]	4,6

The dose factors for Co-60 in discharges to air from B1 and B2 in [mSv/Bq] for infants 1-2 years, children 7-12 years and adults are specifically given in table 3-7, since they are used in the calculation of dose to the reference group in this report. Co-60 is the normally the dominating nuclide for emissions to air but dose calculations include all measured nuclides. For water, Cs-137 has had an increasing importance on dose and is predicted to dominate the dose from emissions to water in the future.

Table 3-7. Dose factors for Co-60 in discharges to air from B1 and B2 and B1+B2 to water. Dose factors for emission points at a lower height (20 m) for B2 are included.

Age categories in reference group	**B1 (113 m) Co-60 air Dose factor** [mSv/Bq]	**B2 (113 m) Co-60 air Dose factor** [mSv/Bq]	**B2 (20 m) Co-60 air Dose factor** [mSv/Bq]	**Unit B1 + B2 Co-60 water Dose factor** [mSv/Bq]
Infants 0-1 years	1,72E-14	1,72E-14	1,21E-13	1,30E-17
Children 1-2 year	2,18E-14	2,22E-14	1,59E-13	2,72E-15
Children 2-7 years	2,16E-14	2,20E-14	1,58E-13	2,33E-15
Children 7-12 years	2,21E-14	2,25E-14	1,62E-13	2,22E-15
Children 12-17 years	2,11E-14	2,14E-14	1,55E-13	1,77E-15
Adults	1,79E-14	1,80E-14	1,28E-13	6,96E-16

Exposure pathways for discharges to water and air

Exposure pathways considered for discharges to water are time spent at the beach (all ages) and fish consumption (all ages except 0-1 years), where almost 100 % of the dose results from internal exposure due to fish consumption.

Exposure pathways that have been taken into account for discharges to air are the following:

- 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

Table 3-8 summarises the exposure pathways for the reference group. The dose factor of the mother nuclide includes effects from the daughter nuclides if they significantly affect the dose received.

The main exposure pathways, listed in [25], vary for different nuclides. For Co-60 the main exposure pathway is due to the deposition of activity on the ground for all age groups.

More thorough investigation of the different exposure pathways is given in [28]. The dose factors for inhalation and intake 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, influence by buildings and release heights, radioactive decay etc. The calculation methods are described in [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 into 10-degree sections and the wind velocity into 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 of the building are not included.
- The plume lift is not taken into consideration.

These assumptions will yield a general overestimation of the calculated dose, [26]. Wind directions with frequencies and velocities are discussed in section 1.4.

Discharges to water

The Barsebäck NPP is located on the shore of Öresund, the inlet to the Baltic sea of Scandinavia. Radionuclides are released to the water of Öresund by one outlet point from the Barsebäck NPP. Discharges to water take place in a batched process, where the radioactive waste water is pumped to the sea.

Figures 3-7 to 3-10 in this report, together with figure 1-1 and 1-2 in section 1.1, describe the geography of the outlet point.

Figure 3-7. The location of the Barsebäck NPP.


Figure 3-8. The location of the Barsebäck NPP.

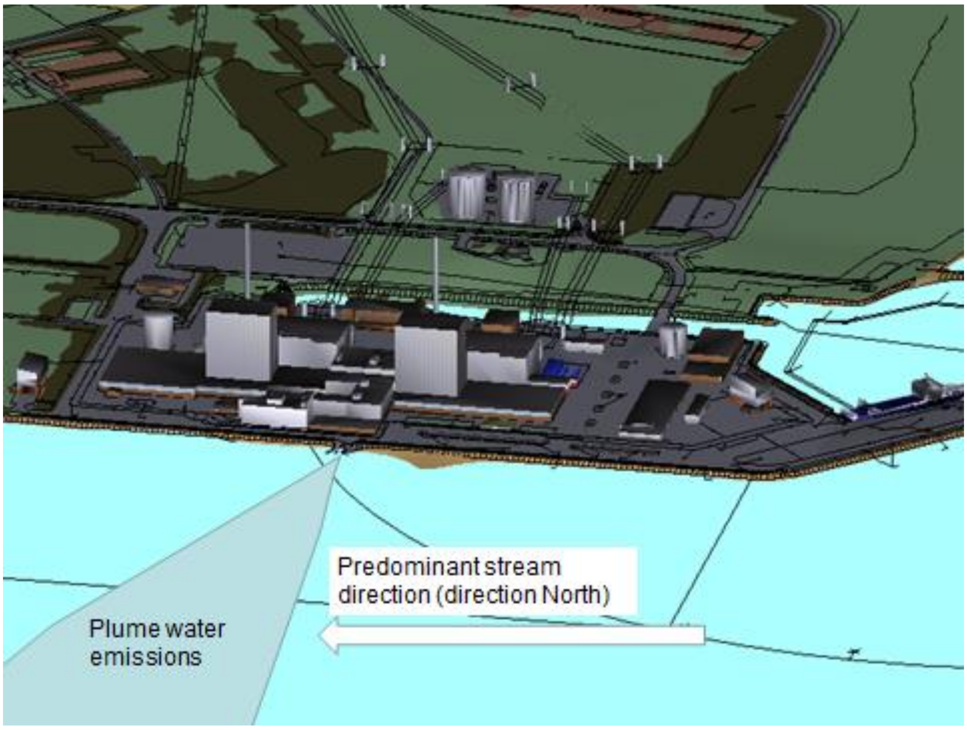


Figure 3-9. Schematic picture of the outlet point for water emissions at the Barsebäck NPP.

The transfer between radionuclides in water and suspended particulates as well as the transfer to fish has been modelled by compartment analysis, as has the sedimentation process [31]. In the model, the discharges are evenly distributed over the year.

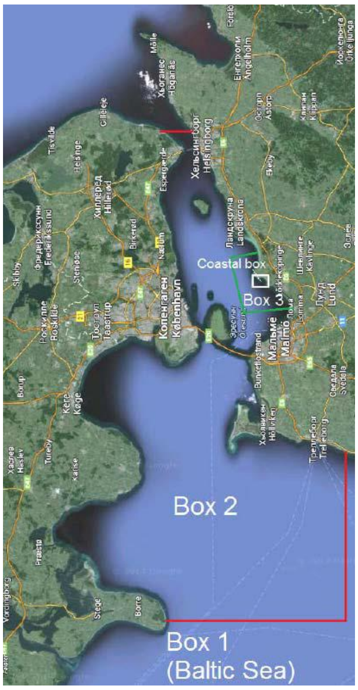


Figure 3-10. Picture of the common strait, Öresund, between Denmark and Sweden. The boxes used in a compartment model for discharges to water are defined.

The coastal box (3) in figure 3-10 has a turnover of 1000 m^3/s. The water turnover in the box is high, so the discharges are efficiently mixed with the surrounding waters. The turnover of water in the box model is highly dominated by the sea water exchange. The volume flow rate from the water release point is low and therefore has no significant effect on the water exchange rate.

The model in [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 etc. There are parameter values given for e.g. annual sediment growth, sinking velocity for particles and quantities of suspended material.

During decommissioning of the plant the flow rate of the discharges to water will decrease from the present flow of 4 m^3/s to only 0,02 m^3/s. The turnover of water in the box nearest to the outlet point is principally independent of the water flow rate of the discharge [7], due to the high flow rate of the sea stream in Öresund. This means that the dose factors from the model, originally based on data for the power plant in operation, will still be valid for decommissioning.

Human habits affecting the dose factors

In [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.

The public's living habits have been predefined as conservative. The hypothetical individuals in the age groups have been assumed to be present near the site throughout the entire year, some of this time indoors. The hypothetical local inhabitants have been presumed to consume fish from the sea. The annual intake of fish has been based on Swedish consumption statistics for different age groups.

Different breathing frequencies and amount of consumed food are applied for the different age groups when calculating the dose factors, for more information, see [28]. For instance, children tend to drink more milk than adults do.

Area description and distance to reference group and different foodstuff

The Barsebäck power plant is located in the municipality of Kävlinge, which has 31 000 inhabitants. The nearest municipalities with major population centres are Landskrona, Lund and Malmö (33,000, 91,000 and 312,000 inhabitants respectively).

Kävlinge municipality has an area of 154 km^2, and the entire Skåne county population of 1,3 million has a total of approximately 11,000 km^2 available. The county is one of the country's most important agricultural areas. Of the total area, 43 % is cultivated land, while 34 % is forest.

The nearest houses are located in Rörbäck (3) and Saltvik (3), see figure 3-11. Barsebäckshamn includes 438 inhabitants, Barsebäck village 524 and Hofterup / Ålstorp 3 500. Löddeköpinge has 6 600 inhabitants.

The routes of exposure to the reference group are listed in table 3-8.

Figure 3-1.1 Detailed overview of the surroundings of the Barsebäck NPP.

Table 3-8. Routes of exposure for reference group [30].

Routes of exposure	Place
Inhalation, external exposure from clouds, external exposure from soil, intake of: fruit, cultivated berries, vegetables and root crop	Saltvik
Intake of meat (by pasturage)	Area between the Barsebäck NPP and Barsebäck Harbour
Intake of cereals, meat and/or milk intake from cows fed with cattle feed from the site	The area direct north of Saltvik
Intake of milk (by pasturage)	High
Intake of seawater fish and shellfish	From sea close to Barsebäck harbour
Intake of water and freshwater fish	Not taken into account
Intake of forest products	Not taken into account
Intake of crawfish	Not taken into account

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

Concentration

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 were calculated; see figures 3-12 and 3-13.

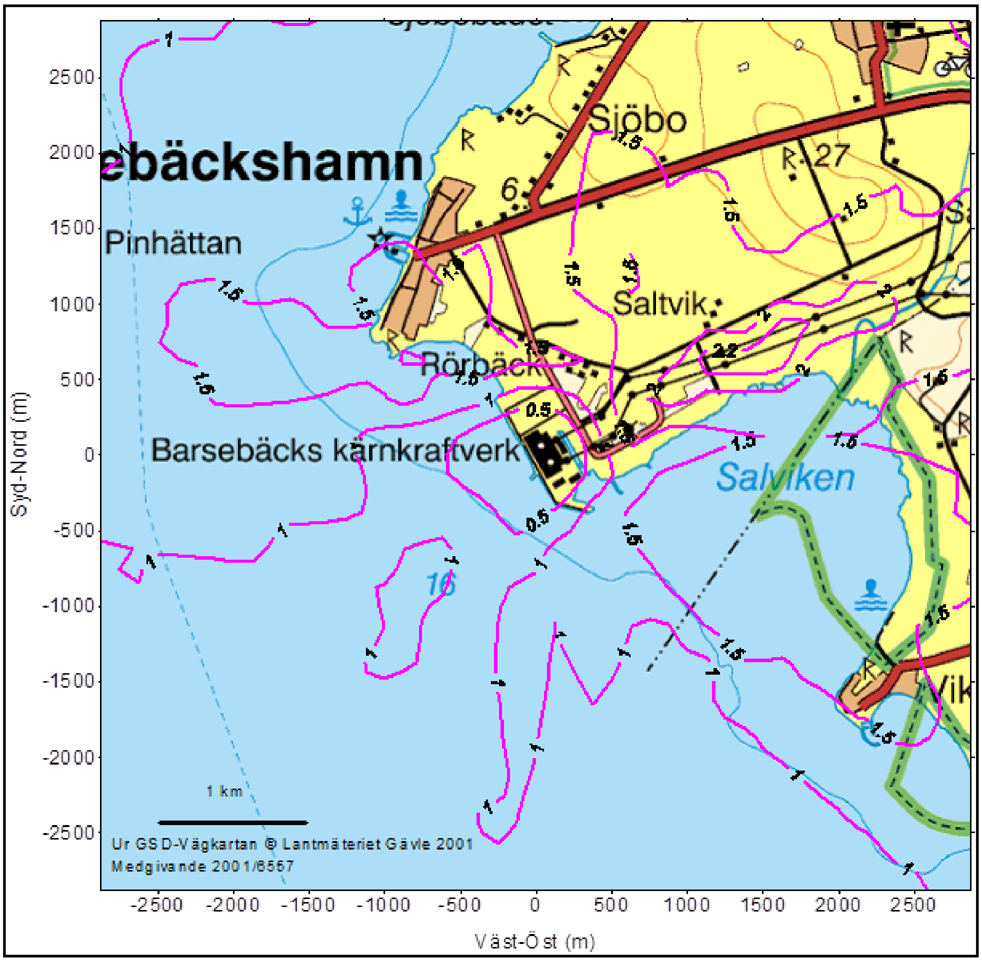


Figure 3-12. Barsebäck. Emission height: 100 m. Estimated annual mean air concentration [10^{-15} Bq/m^3] of Cs-137 with an emission of 1Bq/year [30].

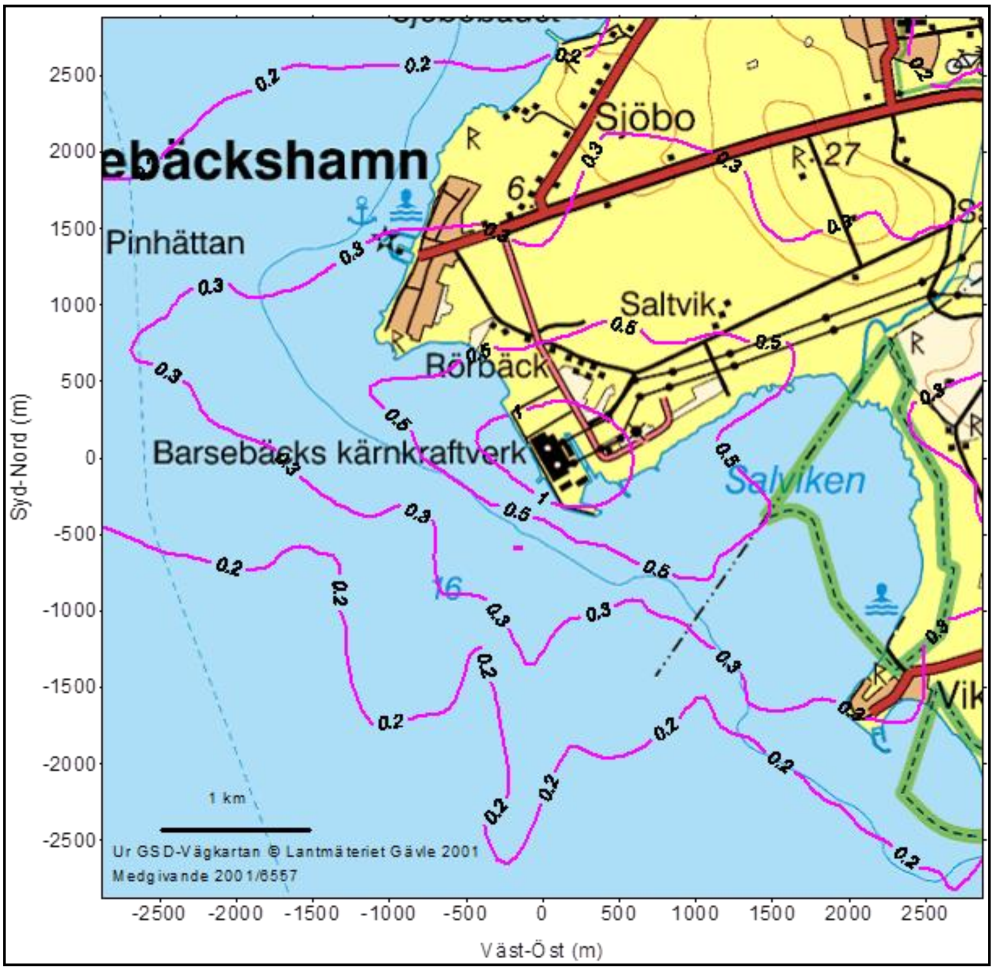


Figure 3-13. Barsebäck. Emission height: 100 m. Estimated annual mean precipitation [10^{-9} Bq/m^2] of Cs-137 with an emission of 1 Bq/year [30].

Dose

Based on the prognosis of Co-60 emissions to air and other nuclides added by nuclide vector for emissions (year 2017), the annual dose can be calculated. The most affected age group in terms of dose is normally 12 – 17 year-old children, for which the results are shown in figure 3-14. The doses received by the different categories are shown in appendices 3 -6.

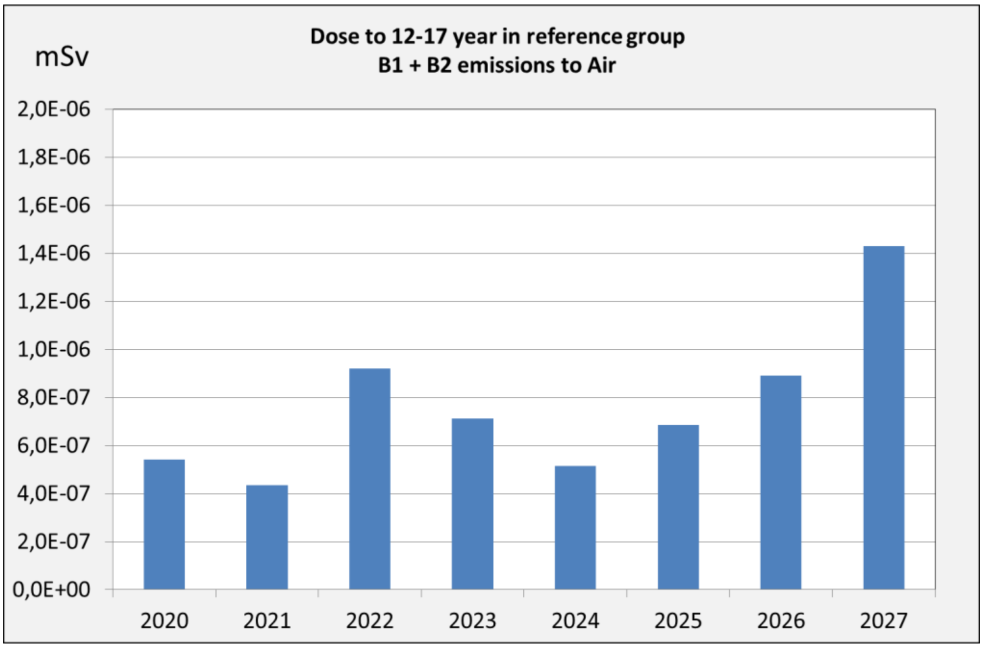


Figure 3-14. Prognosis for doses (12-17 year) from emissions of Co-60 to air from B1 and B2 [22].

The doses are increasing during the time of decommissioning despite the decreasing emissions of Co-60. This is mainly due to the fact that the proportion of the emissions that will come from relatively lower emission points than the main stack will increase during the decommissioning time period.

During power operation, the dose to the reference group was dominated by C-14. The annual dose received was approximately 1E-04 mSv/year. During the period of C&M operation the dose to the reference group has been dominated by Co-60, at a level of 1E-7 mSv/year. The prognosis for emissions during decommissioning corresponds to approximately 1E-6 mSv/year (0,001 µSv/year).

3.5. Interim storage 2

3.5.1. Authorisation procedure in force

The regulations described in section 0 also apply to the construction of interim storage 2. The implementation of the regulations and the data to be used for future reference- and target values that are described in section 3.1.2 also include interim storage 2. Section 3.1.3 also applies to interim storage 2.

3.5.2. Technical aspects

The information in section 3.2 also applies to interim storage 2, except the parts that deal with induced activity, which will not be stored in interim storage 2.

The radioactive inventory in Section 3.2.1 presents the total amount of decommissioning waste for B1 and B2. The activity inventory that will be stored in interim storage 2 is a subset of what is presented in table 3.2. The activity inventory that will be stored in interim storage 2 is calculated at most to the amount 2,2 E12 Bq in 2023, see table 3-9.

Table 3-9. Calculated maximum activity inventory in interim storage 2 [11]. (refers to 2023.)

	Maximum activity in interim storage 2 [Bq]
H-3	1,77E+12
Be-10	6,77E+02
C-14	1,14E+09
Cl-36	2,95E+07
Ca-41	2,91E+09
Fe-55	6,23E+10
Co-60	1,08E+11
Ni-59	6,94E+08
Ni-63	7,64E+10
Se-79	1,07E+03
Sr-90	4,04E+08
Zr-93	1,16E+07
Nb-93m	3,53E+10
Nb-94	9,64E+07
Mo-93	1,17E+07
Tc-99	3,91E+06
Ru-106	6,61E+03
Ag-108m	6,51E+08
Pd-107	1,46E+02
Cd-113m	1,62E+06
Sn-126	1,33E+03
Sb-125	2,77E+08
I-129	7,84E+03
Cs-134	4,57E+07
Cs-135	1,89E+05
Cs-137	8,30E+09
Ba-133	1,53E+08
Pm-147	7,75E+06
Sm-151	6,63E+09
Eu-152	1,33E+11
Eu-154	3,96E+09
Eu-155	5,77E+08
Ho-166m	7,15E+07
U-232	1,01E+01
U-236	4,40E+02
Np-237	4,19E+02
Pu-238	3,83E+06
Pu-239	2,71E+06
Pu-240	9,71E+05
Pu-241	3,62E+07
Pu-242	3,26E+03
Am-241	2,11E+06
Am-242m	1,11E+04
Am-243	3,62E+04
Cm-243	1,19E+04
Cm-244	1,61E+06
Cm-245	3,97E+02
Cm-246	1,22E+02
Total	**2,21E+12**

3.5.3. Monitoring of discharges

The descriptions in sections 3.3.1, 3.3.2 and 3.3.3 are only applicable to activities during D&D, not to the interim storage of radioactive waste in interim storage 2. As no radioactive discharges to air are expected from interim storage 2, it is considered that the building does not require any (forced) ventilation or any permanent air sampling equipment for activity monitoring.

In order to prevent, control and monitor, frequent contamination checks will be performed in the building and on floor surfaces as well as on personnel and vehicles present in the building.

If a spread of surface contamination is confirmed and/or at suspicion of airborne activity the following actions are to be implemented:

- Conduct cleaning in order to return classification to ‘White classification’ for surfaces.
- Any airborne contamination should be monitored by air samplers in the relevant sections of the building. If airborne contamination is confirmed the radioactive discharge to air is to be calculated from conservatively assumed values for the building’s air exchange.
- The building’s air exchange to the environment will be minimised through restrictions on opening of portals.

3.5.4. Evaluation of transfer to man

The height of an inadvertent discharge of radioactive effluent to air from interim storage 2 is about 3 metres.

The generic model for discharge from interim storage 2 is identical to the model described in section 3.4.1.

Concentration curves for discharge from interim storage 2 has in general the same appearance as in figures 3-12 and 3-13 with the difference that the values are about 10 times higher due to the lower emission point.

No discharge of activity to air or to water is expected during normal operation of interim storage 2. Thus the reference group will not receive any contribution of dose from interim storage 2 [11].

3.5.5. Radioactive discharges to atmosphere from other installations

During normal conditions interim storage 2 will not result in any radioactive discharges to the atmosphere.

However if discharges would occur, then the interim storage 2 is subject to the same reporting requirements that apply for the rest of the Barsebäck NPP. Thus the reporting would be included in the regular reporting for the Barsebäck NPP.

The limit value for Barsebäck NPP includes possible discharges from interim storage 2.

4. Release from the installation of liquid radioactive effluents in normal conditions

Information valid for both air and water discharges are given in more detail in chapter 0. In this chapter, only the aspects specific to water discharges are described.

Sections 4.1 - 4.4 are arranged in accordance with the requirements in Annex III (2010/635/Euratom), thus applicable to the existing plant to be decommissioned.

Section 4.5 is arranged in accordance with the requirements in Annex II (2010/635/Euratom), thus applicable to the interim storage 2 to be constructed.

All information presented regarding activity, doses and other radiological analyses are based on the fact that all internal parts from the reactor pressure vessels are stored in the interim storage 1 during D&D and applies both to normal conditions as wells as unplanned discharge of radioactive effluents.

4.1. Authorisation procedure in force

Compliance with requirements that apply during C&M operation, SSMFS 2008:23, is demonstrated by defining reference and target values for the discharges to water. These historical values for discharges of activity to water have generally been much lower than the dose limit of 0,1 mSv/year to the representative individual.

The dose factors for Cs-137 and Co-60 to water are 3,77 E-15 mSv/Bq, respectively 1,77 E-15 mSv/Bq for the most affected category, children 12-17 years old. The dose 10 µSv/year, set by EU, corresponds to the discharge to water of 2,7 E12 Bq/year (Cs-137 alone), or 5,7 E12 Bq/year (Co-60 alone).

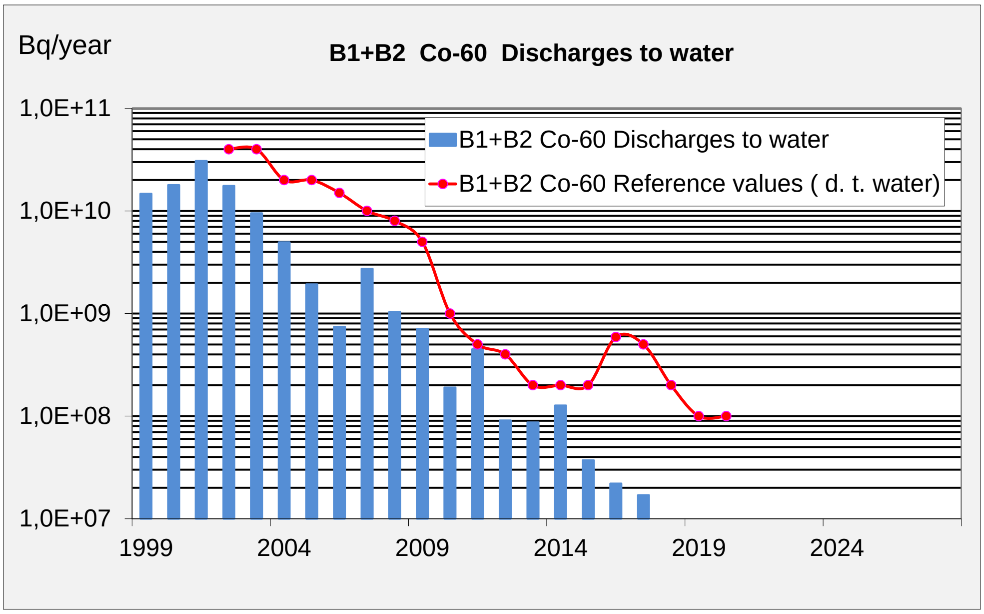


Figure 4-1. Reference values and discharges of Co-60 to water from B1 and B2.

Figure 4-1 shows the reference values and historical discharges from Co-60 to water from B1 and B2. In the red line, the values for 2019 and 2020 are target values whereas the values for the period 2007 – 2018 are reference values.

As for emissions to air, the requirements for discharges to water during decommissioning are defined in [12], constitute the basis for further analyses. See section 0.

4.2. Technical aspects

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

The section 3.2.1 covers also in general the origin of radioactivity in waste water. Most of the activity in the waste water is in particulate form.

The waste water shows very low chemical contamination in general; especially as the Barsebäck NPP sends the laundry to an external facility. The plant has a program in place to reduce the use of chemicals in general and use of all complexing agents in products is banned, in order to ensure the optimum performance of ion exchange resins.

Co-60 has traditionally been the dominating nuclide for discharges to water and the nuclide is found on both system surfaces and in filter systems. The nuclide has been used as the reference nuclide for reducing discharges, both to air and to water. Diagrams presented on activity in this report is therefore on Co-60 even if Cs-137 for water in the future also will have a slightly higher impact on dose. (All diagrams on dose include dose from all nuclides measured.)

4.2.2. Annual discharges expected during dismantling

B1 and B2 have a common waste facility for treating liquid waste. The reference and target values are accounted for together.

Waste water during D&D can be generated by following activities:

- Drainage of pools.
- Decontamination of reactor pressure vessel loose activity.
- Drainage and decontamination of waste water storage tanks.
- Drainage and decontamination of chemical decontamination tanks.
- Use of washer on components.
- Decontamination of pipes, valves etc.
- Use of cooling and cutting fluids.
- Rain leakages.
- Personal hand washing and decontamination.
- Drainage from plant laboratory.
- Use of fire sprinkler system.

Most pool, system and tank drainage will be carried out prior to the D&D starts, and the volume of waste water is expected to be low.

2004/2/Euratom [33] specifies the radionuclides that must be reported from nuclear facilities in discharges to air and water. For discharges to water, gamma-emitting radionuclides, Sr-90, H-3 and alpha-emitting radionuclides are analysed and reported.

Table 4-1 illustrates the prognosis of activity discharges to water from B1+B2 for the time period 2020-2027. Apart from H-3, the activity discharge is dominated by Cs-137, followed by Co-60.

Table 4-1. Prognosis of activity discharges to water from B1+B2 during decommissioning for the time period 2020 - 2027 [22].

	Water [Bq] 2020	**Water [Bq] 2021**	**Water [Bq] 2022**	**Water [Bq] 2023**	**Water [Bq] 2024**	**Water [Bq] 2025**	**Water [Bq] 2026**	**Water [Bq] 2027**
Co-60	1,4E+08	9,6E+07	8,0E+07	5,6E+07	4,1E+07	3,0E+07	2,3E+07	3,3E+07
Cs-137	4,0E+08	3,2E+08	2,9E+08	2,3E+08	1,9E+08	1,5E+08	1,3E+08	2,1E+08
Sb-125	2,5E+07	1,5E+07	1,1E+07	7,2E+06	4,6E+06	3,1E+06	2,0E+06	2,6E+06
H-3	1,1E+10	8,7E+09	7,9E+09	6,0E+09	4,7E+09	3,8E+09	3,0E+09	4,7E+09
Sr-90	1,1E+05	8,6E+04	8,0E+04	6,3E+04	5,1E+04	4,2E+04	3,5E+04	5,7E+04
Pu-238	3,5E+05	2,8E+05	2,6E+05	2,1E+05	1,7E+05	1,5E+05	1,2E+05	2,0E+05
Pu-239/Pu-240	1,8E+03	1,4E+03	1,4E+03	1,1E+03	9,1E+02	7,7E+02	6,6E+02	1,1E+03
Am-241	5,9E+04	4,8E+04	4,5E+04	3,6E+04	3,0E+04	2,5E+04	2,2E+04	3,6E+04
Cm-244	3,5E+04	2,7E+04	2,5E+04	1,9E+04	1,5E+04	1,3E+04	1,0E+04	1,6E+04

Figure 4-2 shows that the prognosis of Co-60 emissions to water has a decreasing trend during 2020 - 2026. On the red line, the values for 2019 and 2020 are target values whereas the values for the period 2007 – 2018 are reference values. The slightly higher value for 2027 is due to the dismantling of the liquid waste building.

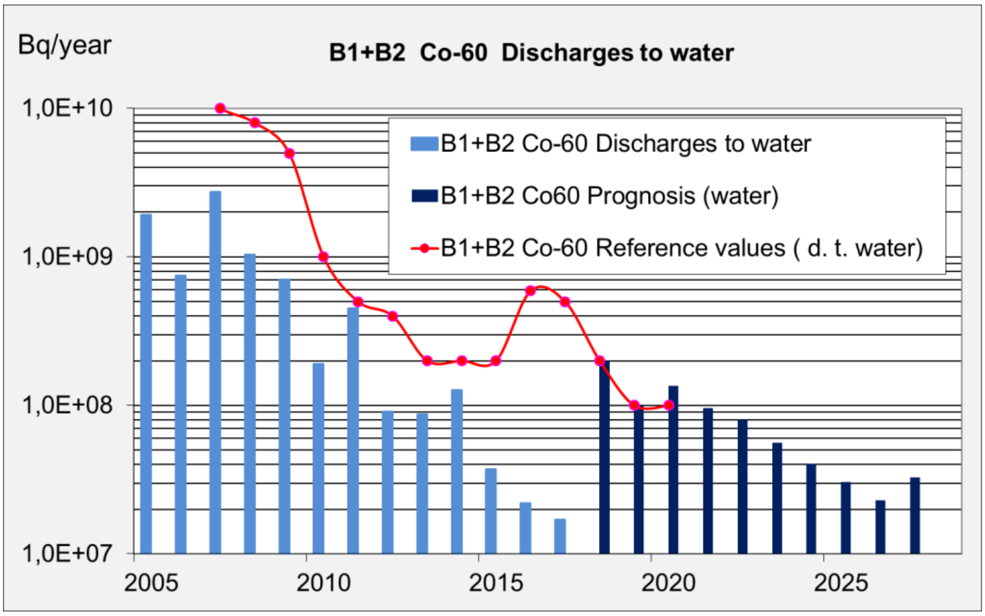


Figure 4-2. Reference values, discharges and prognosis of Co-60 to water from B1 and B2 [22].

4.2.3. Management of the effluents, methods and paths of release

The management of discharges to water is described in section 3.4.1 and in section 4.3.

4.3. Monitoring of discharges

The activity concentration in water that is to be discharged from the liquid waste facility is initially reduced by one or more of the following processes:

- Sedimentation
- Filtration through deep bed powdery ion exchange resin
- Filtration through deep bed grain ion exchange resin.
- Membrane filtration (nano filtration)

The effect of the cleaning processes is monitored by sampling before the water is transferred to one of two discharge tanks. If the concentration of activity exceeds specific limits, or it likely that the activity concentration can be reduced further (BAT), the water is treated by additional filtration.

Before discharging the water there is another sample taken and analysed (gamma-emitting radionuclides and total alpha activity) to ensure a low activity concentration.

The outlet point of the discharges is best described by figure 3-9. The discharges of water take place intermittently, 250 m^3 at a time, during a time of about 4 hours. During C&M operation the discharge volumes have been on average 2000 m^3/year. It is likely that the annual discharge volumes during decommissioning will be lower.

The activity concentration in the tank is measured prior to discharge. The activity concentration (gamma-emitting radionuclides) must below 500 Bq/l. In practise, water is treated by filtration to achieve an activity concentration below 100 Bq/l.

During the discharge of water there is a dose rate monitor with alarm and automatic stop function installed on the outlet pipe, which minimises the risk that a hypothetical hot spot or other non-homogeneously distributed activity is released.

A proportional sample is collected during the discharge of water. The sample is used for the official discharge analyses. All samples from one month are mixed into a monthly sample that is analysed for gamma-emitting radionuclides and tritium. The monthly samples are mixed to a half-year sample where Sr-90 and alpha-emitting radionuclides are analysed.

4.4. Evaluation of transfer to man

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

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

Section 3.4.1 describes the models for both air and water.

4.4.2. Evaluation of the concentration and exposure levels associated with the envisaged discharge limits for the dismantling operations cited in 4.1 above

Concentration

Concentration plots for water (corresponding to air in 3.4.2) are not available; however the spread of activity from the emission point of water is presented in section 3.4.1.

Dose

Based on the prognosis of Co-60 emissions to water the annual dose over the years to the reference group can be calculated. The most affected age group in terms of dose is 12-17 year-old children, for which the results are shown in figure 4-3. The doses received by the different categories are shown in appendix 7.

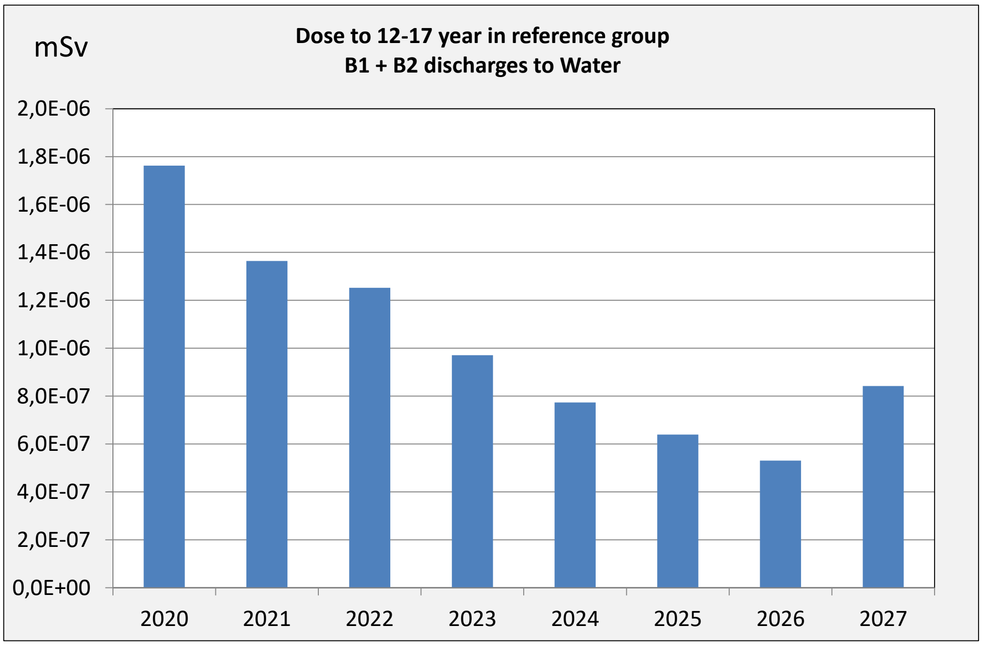


Figure 4-3. Prognosis for the annual doses (12-17 year) from discharges to water from B1 and B2 [22].

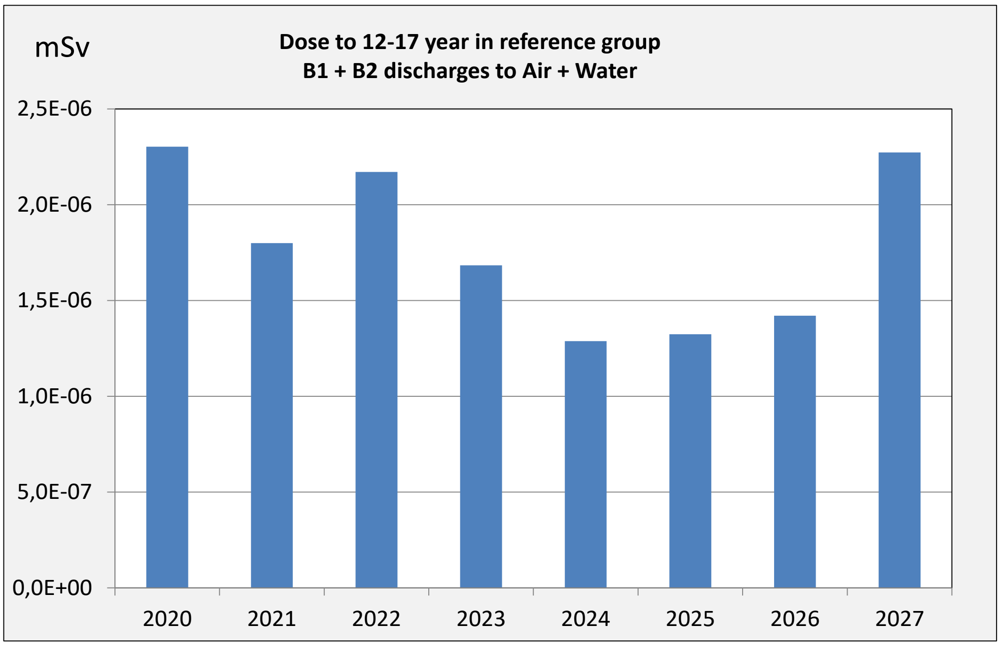


Figure 4-4. Prognosis for the annual doses (12-17 year) from discharges to air and water from B1 and B2 [22].

Figure 4-4 gives the result as the sum of data presented in figures 3-14 and 4-3. The doses received by the different categories are shown in appendix 8.

In total, the prognosticated dose to the reference group will be approximately 0,002 µSv/year, which is significantly lower than the limit of 0,01 mSv/year.

4.5. Interim storage 2

4.5.1. Authorisation procedure in force

This section is not applicable to the interim storage 2 since interim storage 2 will not contain any systems containing water. During normal operations no events have been identified that may lead to discharge of radioactive water from the interim storage 2.

4.5.2. Technical aspects

This section is not applicable to the interim storage 2 since interim storage 2 will not contain any systems containing water. During normal operations no events have been identified that may lead to discharge of radioactive water from the interim storage 2.

4.5.3. Monitoring of discharges

This section is not applicable to the interim storage 2 since interim storage 2 will not contain any systems containing water. During normal operations no events have been identified that may lead to discharge of radioactive water from the interim storage 2.

4.5.4. Evaluation of transfer to man

This section is not applicable to the interim storage 2 since interim storage 2 will not contain any systems containing water. During normal operations no events have been identified that may lead to discharge of radioactive water from the interim storage 2.

4.5.5. Radioactive discharges to water from other installations

The interim storage of radioactive waste in interim storage 2 will not result in any release of liquid radioactive effluents.

However if discharges would occur, then the interim storage 2 is subject to the same reporting requirements that apply for the rest of the Barsebäck NPP. Thus the reporting would be included in the regular reporting for the Barsebäck NPP.

The limit value for Barsebäck NPP includes possible discharges from interim storage 2.

5. Disposal of solid radioactive waste from the installation

Sections 5.1 – 5.4 are arranged in accordance with the requirements in Annex III (2010/635/Euratom), thus applicable to the existing plant to be decommissioned.

Section 5.5 is arranged in accordance with the requirements in Annex II (2010/635/Euratom), thus applicable to the interim storage 2 to be constructed.

5.1. Solid radioactive waste

Waste management during D&D is based on the same principles applicable to an operating reactor and during C&M operation. During D&D a larger amount of waste is produced, compared to C&M operation, that require handling.

The decommissioning waste consists of material destined for free release, radioactive waste and conventional waste. The largest amount of the waste produced is materials with extremely small risk of contamination. BKAB has established a procedure for categorizing such materials. The procedure has been reviewed by SSM. After decision that the categorization is correct, this material is considered and treated as conventional waste.

In preparation of D&D of the Barsebäck NPP all materials are categorised with respect to risk of radioactive contamination. As a basis for the categorisation there is an initial radiological assessment. Classification of waste provides guidance on amount of conventional waste, how the radiological waste can be managed, what type of treatment that is applicable, how to package the waste and how to dispose or otherwise eliminate the waste from the site.

Together with the information regarding where the material has been located, how it has been used and what activities have been performed around it, the materials have been assigned four different categories, so called “risk categories”:

1. Extremely small risk of contamination.
2. Small risk of contamination.
3. Risk of contamination.
4. Contaminated above clearance limit

In practice all material located in radiologically controlled areas are classified in categories 2 to 4 and have to be treated as radioactive waste if the material not can be radiologically cleared. For materials of the first category there are procedures in place to ensure the correct identification of the material. This material will be treated as conventional waste.

Regardless if the waste treatment is performed at Barsebäck or at an external entity, BKAB will always be legally responsible for the waste. The licensee is fully responsible for the radioactive waste created during decommissioning. This responsibility is considered fulfilled as and when the waste has been placed in the final repository.

5.1.1. Categories of solid radioactive wastes and estimated amounts

Waste categories

Radioactive waste is categorised depending on the half-lives of the radionuclides present and the amount of activity in the waste according to SKB's definitions for short-lived/long-lived radioactive waste, see table 5-1. High level waste (nuclear fuel) has already been dealt with and is not included in the management of decommissioning waste during D&D.

Table 5-1. Waste categories.

Category	**Description**	**Surface dose rate [mSv/h]**	**Receiving facility**
Materials for free release	Free release at BVT.	Not applicable	External recipient
Materials for free release (metals) and combustible material	Materials for free release after treatment	< 0,1*	External recipient for treatment.
Short lived Very Low Level Waste, VLLW	Materials for repository disposal.	≥ 0,1 - < 0,5	Surface repository, SFR
Short lived Low Level Waste, LLW	Materials for repository disposal.	≥ 0,5 - < 2	SFR
Short lived Intermediate Level Waste, ILW	Materials for repository disposal.	> 2	SFR
Long lived low- and intermediate level waste	Materials for repository disposal.		SFL

*Refers to the requirements of the recipient.

Solid decommissioning waste consists of metal/scrap metal such as process components, overhead cranes, heat exchangers, chillers, fans, ventilation ducts, pumps and motors and electrical components. Further on different building materials as well as combustible waste such as consumables- and personnel protection equipment is included. Other solid waste included is insulation, concrete, asphalt, sand and soil. Hazardous waste such as asbestos, oil, PCB's, chemicals, electronics etc. will be managed according to their respective properties.

Solid decommissioning waste is subdivided into the following groups depending on their material properties:

- Metals as well as miscellaneous hard solid waste
- Large components *
- Concrete and sand
- Combustible/compactable

*consists of metals but has its own group due to size.

Metals as well as miscellaneous incompressible solid waste

The waste consists of metals with some elements of incompressible solid waste. The metals are primarily stainless steel and carbon steels. Other metals such as aluminium, copper, galvanised steel, lead etc. do occur to a lesser degree. Miscellaneous incompressible solid wastes are for example cables, inert materials and other building wastes.

Large Components

A large component is defined as a component which, when removed from the controlled area, will not fit into a 20-foot shipping container or weighs more than 20 tons.

Concrete and sand

The largest amount of concrete from the D&D will arise during the conventional demolishing of the buildings and is managed according to the procedures for conventional waste. Contaminated concrete will be handled as radioactive waste.

The amount of sand from the D&D originates from the sand filters. The sand will be categorized and collected into suitable packages, for example big bags, which will be placed into shipping containers.

Combustible/compactable waste

The waste consists mainly of scrap metal and trash such as plastics from packaging and covers of components and spaces, rags and personnel protection equipment.

Amounts of waste

It is estimated that D&D of the Barsebäck NPP will produce 419 000 tons of waste, whereof about 37 000 tons of radioactive waste. About 45% of the radioactive waste is estimated to be destined for free release and mainly consists of metal and large components.

The waste amounts provided are based upon data from earlier decommissioning studies. After additional radiological characterisation the distribution into the different categories may change. The studies were based on requirements and guidelines applicable when they were performed. Changed limiting values for Cs-137 may lead to a smaller volume of waste destined for free release. Other nuclides have higher limiting values than previously, which may lead to a greater amount of other wastes being subject to free release.

Table 5-2 describes the distribution of waste amounts in the different groups. Considering the possibilities of managing more waste as subject to free release or managed through a different process than initially assessed the distribution of amounts may change for the different waste categories. Differences in waste amounts between B1 and B2 are mainly due to the fact that the waste facility and ABC-storage belongs to B1.

Table 5-2. Estimated waste amounts (ton).

Waste category	Metal		Large Components		Concrete and sand		Combustible/compactible		Total
	B1	B2	B1	B2	B1	B2	B1	B2	B1+B2
Subject to free release	6200	5200	1 000	1000	0	0	0	0	13 400
VLLW	3200	1600	1200*	1200*	4800	2600	200	200	15 000
LLW	2400	1600	0	0	2800	1200	0	0	8 000
ILW	300	300	0	0	0	0	0	0	600
Total (ton)	**12 100**	**8 700**	**2 200**	**2 200**	**7 600**	**3 800**	**200**	**200**	**37 000**

**2400 tons of metal, VLLW, from large components are estimated to be subject to free release.*

5.1.2. Processing and packaging

Different steps in the waste management process have different requirements. The requirements are based on final recipient, transport, handling and treatment, both internally as well as externally. In the Swedish system, according to Appendix 2, the waste transport container is constructed to fulfil the requirements applicable during transport of waste packages destined for final disposal. When selecting treatment methods, existing requirements are applied so that the waste meets the acceptance criteria for final disposal or free release as well as the transport legislation.

During D&D the waste will be sorted adjacent to the location where it is created or as close to the dismantling site as possible. The waste is sorted according to origin, material type and activity. Thereafter the solid decommissioning waste is treated according to best available technic, radiation-safe handling and the requirements of the final recipient.

From the local decommissioning sites, internal transports transfer the waste to designated waste and repackaging station. From there the waste is transported to buffer stores, awaiting the next step in the process which may be conditioning or storage depending on waste and the requirements of the receiving facility. The packaging used during decommissioning and dismantling are steel or concrete moulds, concrete or steel tanks as well as shipping containers. Waste in shipping containers may be required to be pre-packaged into inner packages such as garbage bags, steel drums or 'Berglöfslåda' (corrugated steel box).

The following management routes have been deemed acceptable for the management of the radioactive waste.

- Free release
- External treatment
- Near Surface repository disposal
- Deep Geological Repository, SFR
- Deep Geological Repository, SFL

Free release
One alternative during management of radioactive waste with low risk/risk of radioactive contamination is free release. The free release of materials, building structures and areas is performed according to the Free release regulation SSMFS 2018:3. Free released materials, building structures as well as ground areas means that they are not considered relevant from a radiation protection perspective to the Radiation Protection Act (2018:396), Radiation Protection Ordinance (2018:506) or the Act on Nuclear Activities (1984:3).

Furthermore, SKB has developed a guideline for free release during D&D of nuclear facilities [34] which BKAB intends to use.

External treatment
In addition to managing materials via direct free release, materials can be treated externally and then be free released. Low level metallic waste may be smelted, and free release is then applied to the produced ingot. The waste producers maintain responsibility over the waste until it has been completely disposed of. External suppliers must be able to show that they have enough resources and capacity to accept the waste that is expected to be delivered to them. In order to avoid any possible interruptions at external waste treatment suppliers from affecting the ongoing dismantling progress and decommissioning it is important to keep options open for waste management, for example surface repository disposal.

Surface repository
A large part of the waste created will be Low Level Waste. Of this low level waste about one third can be categorised as Very Low Level Waste and this may therefore be disposed of in a surface repository.

No surface repository will be established at the Barsebäck NPP as the entire facility will be subject to free release. OKG’s application for a new surface repository for very low level decommissioning waste includes disposal of very low level waste from the Barsebäck NPP. Subject to license/approval is acquired.

If the possibility of using OKG’s surface repository is not realised the waste will be diverted to SFR.

Repository for short lived radioactive waste, SFR
For low and intermediate level waste, where the amount of short lived radionuclides are dominant there is the possibility of disposal in a deep geological repository, SFR, located in Östhammar. At the moment low- and intermediate level operational waste is disposed of here. In order to be able to receive the estimated decommissioning waste an extension of the repository is planned.

SFR is an important part of the Swedish waste management system and is based on a solid and stable design which is suitable for numerous different fractions and materials with different levels of contamination.

Repository for long lived radioactive waste, SFL
SKB is planning to build a repository, SFL for the disposal of long-lived low and intermediate level waste (LLW and ILW). For BKAB this applies for the reactor internals, which are segmented and packaged into steel tanks, as well as for long-lived trash and scrap metal, which are packaged into concrete boxes with bolted lids.

This waste is already handled and is stored in interim storage 1 pending transport to SFL or to external interim storage.

Figure 5-1 provides an overview of the waste management for each waste category and final recipient, where the conventional waste is included. For the radioactive waste the process is adapted to the Swedish system according to Appendix 2.

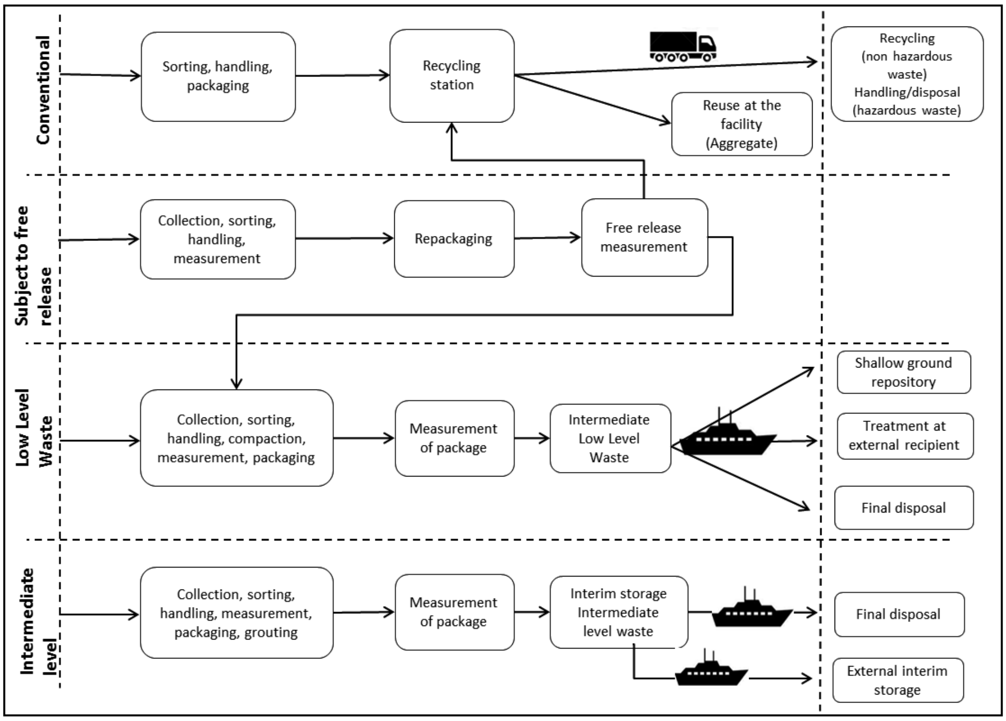


Figure 5-1 Schematic overview of the waste management for each respective waste category.

5.1.3. Storage arrangements on site

During D&D there will be four interim storage buildings which are all located in the harbour area. All the storage locations and storage facilities are located in a controlled area.

- Interim storage facility 1
- Interim storage facility 2
- AB and C storage
- ATB-storage

The storage facilities are described in section 2.4.

5.2. Radiological risks to the environment

For a facility under decommissioning where all nuclear fuel as well as the reactor internals have been removed the overall risk matrix is radically changed regarding radiological environmental impact. During decommissioning the environmental risks consists of discharges to air and water during handling of radioactive components, materials and accidents within the facility, for example fire or leakage of radioactive water. The risk analysis is described in chapter 0 in this report.

The waste management strategy during D&D is based on risk minimization, the responsibility for the staff, the municipality and the environment as well as cost-effective management. Choosing well-established and incorporated processes for handling of waste during D&D reduces the risks of accidents.

Activity monitoring for ventilation systems as well as procedures for fire suppression remain in the facility during decommissioning and dismantling and contribute to limiting and controlling any environmental discharges.

The interim storage facilities are monitored to the extent necessary depending on the type of waste stored there. SKB’s expanded repository for low and intermediate level waste, SFR, is planned to open around 2030 which means that low and intermediate level waste will be stored on site until SFR is commissioned.

Incorrect sorting of waste may occur due to incorrect dose measurements, deficiencies in the labelling of materials or human error management. This could lead to that contaminated material could be free released and treated as conventional material.

Transports of radiological waste within the facility will be carried out in accordance with procedures and requirements applicable to operational waste. Permissible surface contamination on waste packages is <40 kBq/m^2 for beta and gamma radiation and <4 kBq/m^2 for alpha radiation.

The construction of the interim storages is such that the dose rate outside the outer walls will not exceed 2 μSv/h.

Waste handling, internal transports and interim storage of waste packages are not expected to result in any significant radiation risk for the environment provided that the above requirements are met.

External transports fulfil the transport requirements that apply when transporting dangerous goods on land and at sea. When the transport requirements are met, the risks for man and the environment are judged to be small.

In order to ensure that radiological material does not leave the site, vehicles are checked both when entering and leaving the site by radiation measuring.

5.3. Off-site arrangements for the transfer of waste

Decommissioning of a nuclear facility creates a lot of waste and materials that need to be managed. The materials and waste will continuously be transported to external recipients or final repositories when possible. Pending transport, the materials and waste will either be in buffer storage or in interim storage at the site.

Material approved by free release will be handled as conventional waste. Transportation from site will be by land.

SKB, the Swedish nuclear fuel and waste management company operates an established transport system for operational waste based on transportation by sea on m/s Sigrid, see appendix 2.

SKB's transports are mainly conducted by sea where TSFS 2015:66 – Transport Agency's regulations and general guidance regarding transportation at sea of packaged dangerous goods (IMDG-code) [8] applies. For land transportation MSBFS 2016:8 – the Swedish civil contingencies agency's regulations regarding transportation of hazardous goods by road or land (ADR-S) [9] and [10] apply.

During decommissioning the same type of packaging for treated waste is used as during operations. This means that SKB's transport system also can be used for decommissioning waste. Transportation to SFR will go by sea.

The Studsvik facility, where the external treatment facility is located, is a possible recipient for the waste. Transportation to/from the Studsvik facility can be by sea or land.

The Surface repository at OKG is a possible recipient for very low level waste. Transportation to the OKG site will be by sea or land.

The transport container for steel tanks loaded with waste to be shipped to SFL is under development and is not yet available as a part of the transport system. SFL waste will be temporarily stored at the Barsebäck NPP at least until transport containers are available. Transport to SFL or to external interim storage will be by sea.

5.4. Release of material from the requirements of the basic safety standards

SSM has published regulations SSMFS 2008:3, Regulations regarding exemptions from the Radiation Protection Act and regarding free release of materials, building structures and ground areas. The purpose of the regulation is, from the perspective of radiation protection, to facilitate the acceptable and rational management and usage of materials, building structures and ground areas that have been or may be contaminated with radioactive substances resulting from activities involving ionising radiation, but which from the radiation protection perspective do not need to comply with the Radiation Protection Act (2018:396) and Radiation Protection Ordinance (2018:506) or the Act on Nuclear Activities (1984:3) and can be free released.

The regulation includes changes to the free release of materials, building structures and ground area that are adapted to the new safety norms in accordance to directives in 2013/59/Euratom.

SSM may grant exemptions from these regulations if there are reasons for doing so and if there is no unacceptable risk to humans or the environment being subjected to detrimental effects from radiation.

SSMFS 2018:3 stipulates the following clearance levels:

Clearance levels for materials and building structures

Materials

Section 12 *The clearance level for radioactive contamination on a material's outer surfaces, and, when applicable, inner surfaces, calculated as a mean value over 0.03 square metre, is as follows:*

1. For tritium, nickel-59 and nickel-63 in total, 40 megabecquerel per square metre,

2. For carbon-14, chlorine-36, iron-55 and technetium-99 in total, 4 megabecquerel per square metre,

3. For other beta-emitting and gamma-emitting radionuclides in total, 40 kilobecquerel per square metre, and

4. For alpha-emitting radionuclides in total, 4 kilobecquerel per square metre.

As far as concerns objects with a total surface area less than 0.03 square metre, 0.03 square metre may be used as a basis for calculating the mean value.

The first paragraph is not applicable to liquids, finely dispersed materials nor other materials lacking a surface that can be checked.

Section 13 *As far as concerns materials other than those stipulated in Sections 14 and 15, in addition to the provisions of Section 12, the clearance levels for the concentration of radioactive substances shown in Appendix 2 shall apply, as per the provisions of Appendix 5.*

As far as concerns samples with a mass less than 1 kilogram, 1 kilogram may be used as a basis for calculating the concentration of radioactive substances.

Section 14 *As far as concerns oil sent for incineration and other hazardous waste sent for incineration or disposal, in addition to the provisions of Section 12, the clearance levels for the concentration of radioactive substances shown in Appendix 3 shall apply, as per the provisions of Appendix 5.*

The provisions of the first paragraph apply to amounts totalling less than 100 tonnes of oil per calendar year, as well as to 10 tonnes in the case of other hazardous waste per calendar year.

Section 15 *As far as concerns personal objects and tools or equipment that will continue to be used for their original purposes and which may only have become contaminated on surfaces that are accessible for checks for contamination, the clearance levels stipulated in Section 12 shall apply.*

Clearance levels for building structures

Building structures

Section 16 *As far as concerns building structures, the clearance levels shown in Appendix 4 shall apply, as per the provisions of Appendix 5.*

Clearance levels for sites and areas

Section 17 *The Swedish Radiation Safety Authority may, after application from the licensee, decide on clearance levels for a site or area. The clearance levels are to be based upon the criterion that the annual effective dose that a member of the general public is likely to receive as a result of the radioactive contamination of the site or area should not exceed 0.1 millisievert.*

The clearance levels for a site or area where restrictions shall apply to continued use following release of such site or area shall, in addition to the provisions of the first paragraph, be based upon the following:

1. The site or area will be freely used after the restrictions have ceased to apply, and

2. A member of the general public is not likely to receive an annual effective dose exceeding 1 millisievert if the site or area would be used freely prior to the point in time when the restrictions are intended to cease.

An application regarding clearance levels for a site or area is required to contain the information stated in Appendix 6.

Section 18 *Prior to release of a site or area for use subject to restrictions, consultation regarding the site's or area's future use and the need for restrictions shall be conducted with involved competent authorities and local interested parties. This consultation shall be documented.*

Specified appendices are found in SSMFS 2018:3.

Furthermore, SKB has published guidelines regarding free release for decommissioning and dismantling of nuclear facilities, [34].

Free release of materials is carried out continuously under NoR in order to minimize the amount of radioactive waste that must be placed in repository.

The D&D of the Barsebäck NPP will produce about 37'000 tons of radioactive waste. About 45% of the radioactive waste is estimated to be destined for free release

Table 5-2 shows that it is mainly metal that is considered suitable for free release. To the quantities indicated in the table, 2400 tonnes of short-lived very low-level waste (metal) from large components are also able to be free released after treatment.

Out of the total amount of concrete (building materials) approximately 99 % can be free released.

5.5. Interim storage 2

5.5.1. Solid radioactive waste

The function of the interim storage 2 is mainly to store shipping containers with VLLW and LLW but other radioactive waste, such as large components, may also be stored there. No treatment or conditioning of the waste will take place inside the building. No waste will be created due to the operation of the interim storage.

5.5.2. Radiation risks to the environment

No waste will be created due to the operation of the interim storage that may affect the environment. The building's design is such that the dose rate outside the outer walls will not exceed 2 μSv/h.

5.5.3. Off-site arrangements for the transfer of waste

The interim storage 2 is only a storage building. No radioactive waste is created due to the temporary storage of large components and shipping containers filled with waste. Removal of low level waste is described in chapter 5.3.

5.5.4. Release of materials from the requirements of the basic safety standards

When the interim storage 2 has been emptied, i.e. stored waste has been transported to SFR, it is expected that the interim storage will fulfil the criteria for free release as only solid waste in containers and large components have been stored in the building. After free release the interim storage 2 will be conventionally demolished.

6. Unplanned discharge of radioactive effluents

Chapter 6 is arranged in accordance with the requirements in Annex III and Annex II (2010/635/Euratom), thus applicable to both the existing plant

to be decommissioned and the interim storage 2 to be constructed.

Exception is section 6.3.4 that is directed exclusively to interim storage 2.

6.1. Review of accidents of internal and external origin which could result in unplanned releases of radioactive substances

Under the Act on Nuclear Activities the licensee of a nuclear facility must verify that the probability of serious disturbances or accidents is low and that, should such an event nevertheless occur, the consequences to the environment and personnel are acceptable.

SSM stipulates [12] that for D&D analysis relevant for safety shall be performed, and that the analysis relevant for safety shall be based on a systematic inventory of events, event sequences and conditions which can lead to harmful effects from ionizing radiation on human health and to the environment or uncontrollable dispersion of radioactive substances. Relevant analyses are included in the SAR, which must be approved by SSM before starting decommissioning.

The two units have for a long time been in C&M operation, which means that all the nuclear fuel has previously been transported off site and the risk of major radioactive releases has thus been minimised. Furthermore, there are no inherent driving mechanisms such as high temperatures or high pressure that can lead to discharge of activity. When entering C&M operation the risks for incidents were minimised by, for instance, minimizing the amounts of oils and chemicals in the facility.

When D&D commences, radioactive material from the reactor internals have been moved to interim storage 1 and systems have been decontaminated. For D&D the total activity in the reactor building is therefore less than it was during C&M operation. Specific accidents concerning reactor internals in the reactor building are therefore not relevant for D&D. Accidents concerning reactor internals are instead analysed for interim storage 1 as part of the SAR for D&D.

Furthermore several systems have been drained of process liquids, one of the pools in the reactor hall has been drained and the fire suppression system has been modified to be activated manually, which are measures that reduce the risk of internal flooding.

One effective measure to further minimise the consequences to the environment during D&D is to reduce the amount of combustible radioactive material in the plant, since fire is the event that can lead to the highest release of radioactivity to the environment.

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

1. Mapping of rooms, systems and components that contain radioactive material, which can lead to release of activity.

2. Mapping of events, with respect to possible events that can occur during power operation and C&M operation.
3. Evaluation of events that are relevant for D&D, with respect to (1.) and (2.) and the experiences gained from C&M operation.
4. Identification of limiting events with regard to radioactive releases.

Sections 6.1.1 and 6.1.2 in this report describe in more detail the most relevant events. Information in references [14], [35], [36] and the safety analysis report 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. The safety analysis report for power operation was used when the safety analysis report for C&M operation was documented. The latter has then been used when documenting the safety analysis report for D&D.

In this report information about the geological and hydrological situation at the nuclear power plant is described in chapter 0. Most of the events from C&M operation are relevant also for the decommissioning in the sense that the effect on buildings are the same and that possible radioactive releases are similar.

The following external events have been analysed or considered and assessed for D&D with respect to release of activity to the surroundings:

- Extreme rain, snow or wind
- High and low sea level
- High temperature in the sea (water supply)
- Pollution and other transients in the water supply
- Lightning
- Earthquake
- Airplane crash

The external events are assessed in the safety analysis report, where it is stated that, except highly improbable events, internal fire can cause higher releases of radioactivity to the surrounding than all the external events. Highly improbable events (e.g. earthquake and airplane crash) are not analysed further for D&D, as was the case for C&M operation.

6.1.2. Internal events

The safety analysis report for a plant in power operation and normal outage contains information regarding internal events. The safety analysis report for power operation was used when the safety analysis report for C&M operation was published, which then has been used when documenting the safety analysis report for D&D.

The following internal events have been analysed or considered and assessed for D&D with respect to release of activity to the surroundings:

- Internal fire
- Internal flooding
- Lifting accidents (load drop)

- Faults in the power supply
- Faults in the ventilation system
- Faults regarding instrumentation and control
- Events that can cause missiles

In order to find the most relevant events for D&D the above mentioned events have been analysed and evaluated further on the basis that the units no longer contain any spent fuel or reactor internals located in the reactor pressure vessels and that there are no driving mechanisms such as high pressure or high temperatures.

Experiences from C&M operation [35] have been utilised when concluding that fire is the limiting event regarding release of radioactivity to the surroundings. The limiting event is hence a fire in the building or in the fire cell which contains the most combustible radioactive material.

6.1.3. Risks during interim storage

The safety analysis report for D&D evaluates the risks for the interim storage facilities.

It is shown that the construction of the storage facilities and the usage of the facilities are such that the risks for an event that can lead to radioactive release are minimised. There are no pressurised water systems in the storage area that can lead to flooding, and the risk of fire is minimised, since an initiating source for fire is limited and the amount of combustible materials in the building is limited as much as possible.

6.2. Reference accident(s) taken into consideration by the competent national authorities for evaluating possible radiological consequences in the case of unplanned releases

SSM has not considered any specific accidents during D&D, since this is the responsibility of the operator of the nuclear power plant.

According to section 6.1 the limiting event for potentially generating external release to the surroundings is a fire in the building or the fire cell containing the most combustible radioactive material. According to [14] and the safety analysis report the following events are hence the limiting events:

- Fire in the AB- and C-storage facility (solid waste storage)
- Fire in the Waste treatment facility for liquid waste (liquid waste facility)

In the safety analysis report it is shown that radioactive releases from other possible events are less than the limiting events. The limiting events have been analysed with regard to releases to the atmosphere and the aquatic environment, as presented in section 6.3.

6.3. Evaluation of the radiological consequences of the reference accident(s)

Four reference cases were studied, where two of the cases entail releases to the atmosphere and two cases entail releases to the aquatic environment.

In the following (I – IV), the assumptions used to calculate the atmospheric and liquid releases are stated. In all cases a deterministic conservative emitted activity was determined [36].

I. To water – 1/3 of the residual contaminating activity in the liquid waste facility. Spent ion exchange resins not included.
II. To water – 1/3 of the residual contaminating activity in the liquid waste facility. Spent ion exchange resins included.
III. To air – 1/3 of the residual contaminating activity in the liquid waste facility. Spent ion exchange resins included.
IV. To air – 1/3 of the residual contaminating activity in the solid waste storage.

See table 6-1 for emitted activity for reference cases.

Table 6-1. Emitted activity for reference cases of decommissioning. (Ref. date 2019-01-01).

	To water [Bq]		To air [Bq]	
Ref. case	**I**	**II**	**III**	**IV**
H-3	0,0E+00	2,1E+05	2,1E+05	6,5E+06
Be-10	0,0E+00	7,1E-03	7,1E-03	2,3E-01
C-14	1,9E+07	2,4E+08	2,4E+08	1,3E+08
Cl-36	4,1E+03	1,9E+05	1,9E+05	1,6E+05
Ca-41	0,0E+00	1,1E-11	1,1E-11	3,4E-10
Fe-55	5,8E+07	2,1E+10	2,1E+10	7,7E+10
Co-60	2,1E+09	1,4E+11	1,4E+11	3,4E+11
Ni-59	1,0E+07	6,5E+08	6,5E+08	2,5E+09
Ni-63	1,1E+09	7,5E+10	7,5E+10	2,8E+11
Se-79	1,8E+01	4,1E+02	4,1E+02	9,6E-01
Sr-90	1,0E+07	1,7E+09	1,7E+09	1,9E+08
Zr-93	3,8E+02	1,0E+06	1,0E+06	4,8E+07
Nb-93m	1,7E+09	6,5E+10	6,5E+10	1,2E+11
Nb-94	4,9E+06	2,0E+08	2,0E+08	2,4E+08
Mo-93	7,7E+04	4,0E+06	4,0E+06	1,9E+07
Tc-99	2,7E+05	5,9E+06	5,9E+06	1,6E+06
Ru-106	1,8E+04	6,2E+04	6,2E+04	7,4E+03
Ag-108m	1,7E+06	7,4E+07	7,4E+07	3,0E+08
Pd-107	2,7E+01	6,0E+02	6,0E+02	1,4E+00
Cd-113m	2,9E+01	6,1E+02	6,1E+02	2,3E+02
Sn-126	1,3E+02	3,0E+03	3,0E+03	2,5E+03
Sb-125	3,6E+06	9,6E+08	9,6E+08	2,7E+09
I-129	7,5E+02	6,2E+04	6,2E+04	4,1E+04
Cs-134	1,4E+06	2,4E+07	2,4E+07	5,5E+06
Cs-135	8,6E+03	7,2E+05	7,2E+05	4,7E+05
Cs-137	7,2E+08	4,0E+10	4,0E+10	2,7E+10
Ba-133	2,1E+00	4,3E+01	4,3E+01	2,5E+01
Pm-147	1,4E+05	1,5E+06	1,5E+06	2,1E+06
Sm-151	6,8E+04	2,2E+06	2,2E+06	1,3E+06
Eu-152	5,0E+02	1,1E+04	1,1E+04	7,1E+04
Eu-154	1,7E+05	5,2E+06	5,2E+06	2,9E+06
Eu-155	2,1E+04	5,6E+05	5,6E+05	3,4E+05
Ho-166m	8,2E-01	1,9E+01	1,9E+01	1,6E+01
U-232	5,0E-01	2,5E+01	2,5E+01	3,2E+02
U-236	2,1E+01	6,8E+02	6,8E+02	1,3E+03
Np-237	2,0E+01	3,7E+03	3,7E+03	3,3E+03
Pu-238	2,2E+05	3,0E+07	3,0E+07	2,5E+07
Pu-239	4,9E+04	1,0E+06	1,0E+06	1,5E+06
Pu-240	7,1E+04	1,5E+06	1,5E+06	2,5E+06
Pu-241	2,0E+06	5,8E+07	5,8E+07	1,1E+08
Pu-242	1,5E+02	2,8E+03	2,8E+03	8,0E+03
Am-241	9,2E+04	3,5E+06	3,5E+06	5,7E+06
Am-242m	5,1E+02	9,3E+03	9,3E+03	2,7E+04
Am-243	1,6E+03	3,6E+04	3,6E+04	9,1E+04
Cm-243	5,9E+02	9,8E+03	9,8E+03	3,3E+04
Cm-244	8,4E+04	2,5E+06	2,5E+06	4,8E+06
Cm-245	1,8E+01	3,4E+02	3,4E+02	9,7E+02
Cm-246	5,5E+00	1,0E+02	1,0E+02	3,0E+02

6.3.1. Accidents entailing releases to atmosphere

For the emissions to air the dose assessment was conducted by adding the result of one initial short term dose assessment to the result of one long term dose assessment.

Short term dose assessment

Calculations of doses to persons in the environment for activity emissions with deterministic weather parameters were carried out using the SSM calculation program LENA 2003 [37]. Dose calculations are made in LENA 2003 for airborne activity to the immediate area from a defined source of emissions. The program is based on a Gaussian dispersion model in three dimensions and the weather is categorised according to input parameters such as stability class (Pasquille), wind speed and mixing height.

Dose calculations were performed for the nuclides Co-60 and Cs-137 for an adult in a distance of 1 km without rain and with rain standing in the wind direction from the emission point. The person is assumed to be outdoors and unshielded from the cloud throughout the release and the exposure pathway includes dose from cloud radiation, inhalation (for an adult integrated dose below 50 years and for children 70 years after activity inhalation) and dose from fallout on the ground during a stay of 6 hours. The following parametric matrix has been used in the calculations of the reference values, see table 6-2.

Long term dose assessment

For the calculation of dose from activity emission to air for the long term process, especially due to internal exposure, the same methodology as described for the calculation of emissions to during normal operation was used, see section 3.4. For air emissions, dose factors for the emission point 20 m were used.

Estimated dose for long-term progression cannot be divided into "no-rain" or "rain" because it is a time-integrated dose calculation based on the metrological statistics that exist in the area around the Barsebäck NPP.

Table 6-2. Matrix of parameters used in LENA 2003 calculations [36].

Parameters		**In the wind direction Distance 1 km No rain**	**In the wind direction Distance 1 km Rain**
Stability class by Pasquille		D meandering wind	D meandering wind
Wind speed Dose point distance x, wind direction Dose point distance y, transverse wind direction	[m/s] [m] [m]	2 1000 0	2 1000 0
Plume mixing height	[m]	800	800
Plume lifting effect	[MW]	0	0
Rain	[mm/h]	0	0,5
Rain start	[m]	0	0
Rain stop	[m]	0	10000
Height of emission	[m]	20	20
Delay time	[h]	0	0
Durance of emission	[h]	2	2
Time for dose integration (except inhalation)	[h]	6	6
Emitted activity	[Bq]	*See table 6-1*	*See table 6-1*
Emitted fraction (Co-group)		1	1
Deposition constant. , nuclides except iodine		0,001	0,001
Filter factor inhalation Shielding factor ground Shielding factor cloud Weathering fast fraction		1 1 1 0	1 1 1 0

6.3.2. Accidents entailing releases into an aquatic environment

For the calculation of dose from liquid releases for the long term process, the same methodology as described for the calculation of emissions to during normal operation was used, see section 3.4.

6.3.3. Results from the dose calculations

Releases to atmosphere

Table 6-3 presents the doses from the calculations for the two reference cases which results in air emissions. The maximum dose nearby the Barsebäck NPP site is found to be 0,09 mSv for reference case IV (emission from solid waste storage). The difference between no rain and rain is small. Primarily, the total inhalation dose is the most important in terms of dose effect for the two reference cases, as it is the largest component of the total effective dose. It is worthwhile to note that the estimated dose represents 9 % of the limit value (1 mSv) [1] for the population in the reference group. Also, no significant export of crops or meat exists to other EU member states. Therefore, a dose assessment for the population in other member countries is not required.

Table 6-3. Calculated doses to a reference group for a deterministic unplanned activity emission to air during decommissioning [36]. (Ref. date 2019-01-01).

Ref. Case	**III**		**IV**	
Emissions	**Liquid waste facility**		**Solid waste storage**	
Emitted activity of Co-60 [Bq]	1,38E+11		3,39E+11	
Emitted activity of Cs 137 [Bq]	4,05E+10		2,69E+10	
Emitted activity of Pu-238 [Bq]	2,97E+07		2,54E+07	
Emitted activity of other radionuclides [Bq]	*See table 6-1*		*See table 6-1*	
Other information;	*See table 6-2*		*See table 6-2*	
Rainfall	No rain	Rain	No rain	Rain
Short term dose - During emission (2h) and following 4h				
Highest activity conc. in air (Co-60 + Cs-137) [Bq/m^3]	3,3E+06	3,3E+06	6,8E+06	6,8E+06
Highest activity conc. on ground (Co-60 + Cs-137) [Bq/m^2]	3,3E+03	1,4E+04	6,7E+03	2,8E+04
Dose from cloud (Co-60) [mSv]	1,2E-04	1,2E-04	2,9E-04	2,9E-04
Dose from fallout (Co-60) [mSv]	1,3E-04	5,2E-04	3,1E-04	1,3E-03
Dose from cloud (Cs-137) [mSv]	8,3E-06	8,1E-06	5,5E-06	5,4E-06
Dose from fallout (Cs-137) [mSv]]	8,8E-06	3,7E-05	5,9E-06	2,4E-05
Dose from fallout total [mSv]	1,3E-04	5,6E-04	3,1E-04	1,3E-03
Dose from fallout total [mSv]	1,3E-04	1,2E-04	3,0E-04	2,9E-04
Committed dose from inhalation total [mSv]	1,7E-02	1,6E-02	2,6E-02	2,5E-02
Short term dose total [mSv]	**0,017**	**0,017**	**0,026**	**0,026**
Long term dose, intake included[mSv]	**0,032** [1]		**0,061** [2]	
Dose Total [mSv]	**0,049**	**0,049**	**0,087**	**0,088**

[1] Highest dose was obtained for the age 12-17 year.

[2] Highest dose was obtained for the age 7-12 year.

Discharges to the aquatic environment

Table 6-4 presents the dose from the calculations for the two reference cases that give rise to water emissions. The maximum dose due to unplanned activity emission to water is 0,5 μSv (indicated in bold numbers for reference case II). The relatively low value for the age group 0-1 years is because infants are assumed not to be swimming in the sea and thus the dose due to direct radiation and intake is significantly lower than for other age groups, which is also reflected in the calculation results.

The calculations demonstrate that the dose is below the limit value of 1 mSv set by the European Commission [1]. Also, no significant export of crops, meat or fish exists to other

EU member states. Therefore, no dose assessment for the population in other member countries is required.

Table 6-4. Calculated doses for a deterministic unplanned activity emission to water during decommissioning [36]. (Ref. date 2019-01-01).

	Adult [mSv]	**0-1 year [mSv]**	**1-2 year [mSv]**	**2-7 year [mSv]**	**7-12 year [mSv]**	**12-17 year [mSv]**
Ref. Case I	4,06E-06	2,86E-08	**7,21E-06**	6,44E-06	6,87E-06	6,69E-06
Ref. Case II	2,47E-04	1,82E-06	**4,86E-04**	4,35E-04	4,55E-04	4,30E-04

6.3.4. Interim storage 2

For the new interim storage 2 dose assessments to air and water have been made based on deterministic assessments of activity emissions from the storage (1/3 of the activity defined in table 3-9 emitted to air and water respectively) [11].

The emitted amount of activity from the interim storage 2 to water can be set in relation to corresponding reference case II for D&D. Emitted amount from deterministic reference case for interim storage 2 is 27 % of the equivalent for D&D. Conservatively, this means that the dose to a critical group is less than 2 μSv for emissions to water from interim storage 2.

Correspondingly, the released amount of activity from interim storage 2 to air can be set in relation to the corresponding reference case IV for D&D. Emitted amount from deterministic reference case for interim storage 2 is 11 % of the corresponding for D&D. Conservatively, this means that the dose to the critical group is below 10 μSv for emissions to air from the interim storage 2.

The estimated maximum doses to air and to water are both below the limit value of 1 mSv set by the European Commission [1]. Also, no significant export of crops, meat or fish is exported to other EU member states. Therefore, no dose assessment for the population in other member countries is required.

7. Emergency plans, agreements with other member states

Since all nuclear fuel has been transported off-site to a licenced facility (Clab), see section 0.1, data regarding emergency plans and agreements with other member states are not required according to chapter 7 in Annex III (2010/635/Euratom).

8. Environmental monitoring

Sections 8.1 - 8.3 are arranged in accordance with the requirements in Annex III and Annex II (2010/635/Euratom), thus applicable to both the existing plant to be decommissioned and the interim storage 2 to be constructed.

8.1. General Description

Environmental radiological monitoring is conducted in the surrounding areas of the Barsebäck NPP and the monitoring constitutes a complement to the measurements of the discharges to air and water which describe the composition and magnitude of the release. The purposes of the environmental radiological monitoring are to detect larger unmonitored releases, to assess the long-term trends of environmental radioactivity around the nuclear site and to test the calculations models applied to estimate the radiation dose to humans [38]. Another objective is to evaluate possible effects on biota. Furthermore, the monitoring program also aims to obtain information that can be provided to the public about the radioactivity presence in the environment and to be used for international reporting of data.

SSM requires nuclear facilities to monitor the environment in accordance with a monitoring programme specified by SSM in the licence conditions for decommissioning [12]. The site-specific monitoring programmes are divided into a terrestrial and a marine part and the content of the programme is described in the SSI (the former Swedish Radiation Protection Authority) report 2004:15, where detailed instructions regarding the sampling location, sampling type, sample treatment, analysis, radionuclides to be measured, reporting, archiving, etc. are given [38]. The activity concentration or the minimum detectable activity (MDA) levels of specified radionuclides are reported to SSM.

According to the licence conditions for decommissioning, [12], the licence holder will be responsible for the content of the monitoring programme. The monitoring program shall consider emission points relevant to D&D and the program must be approved by SSM.

8.2. The environmental radiological monitoring at the Barsebäck NPP

A basic programme involving monthly, quarterly and bi-annually (summer and/or autumn) sampling is conducted each year comprising samples from both the marine and terrestrial environment, in addition to the basic programme, extended sampling is also conducted every fourth year [39]. The extended programme focuses exclusively on samples taken in the marine environment and covers a wider geographical area.

There are currently a total number of 28 sampling stations within 24 km from the Barsebäck NPP where the terrestrial programme consists of natural vegetation. In addition, sludge is sampled from wastewater treatment plants 10 kilometres from the Barsebäck NPP. The marine program includes samples from algae, sediment, fish and molluscs. The positions of the sampling stations are shown in figure 8-1. Table 8-1 and 8-2 summarises the content of the basic and extended programmes. The collected species are chosen based on how well they represent the geographical area and their ability to accumulate radionuclides. The Swedish University of Agricultural Sciences (SLU) conducts the sampling and the sample preparation and analyses are performed at the Barsebäck environmental laboratory.

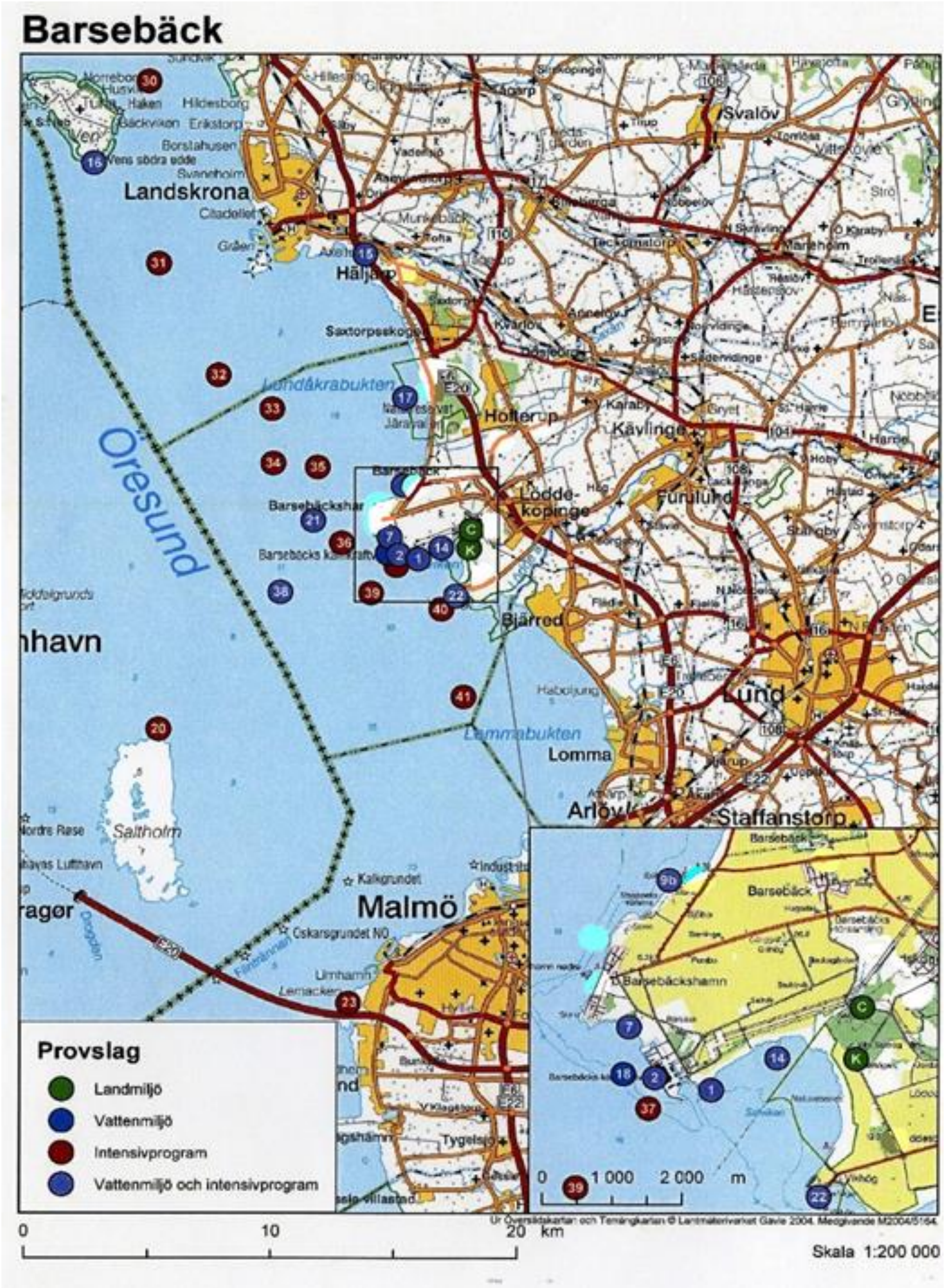


Figure 8-1. Environmental sampling stations in the vicinity of the Barsebäck NPP.

Table 8-1. The Barsebäck NPP terrestrial and marine environmental base programme.

Terrestrial environmental base programme				
	Sample types	**Number of samples**	**Sampling Point**	**Sampling frequency**
Natural vegetation	Moss	2	C, K	Summer
Sludge		2	Kävlinge, Borgeby	Summer/Autumn
Marine environmental base programme				
Sediment		1	38	Quarterly
Algae	Biofouling	2	1a, 7c	Monthly, Mars-November
Algae	Bladderwrack*	7	1, 7, 9b, 14, 15, 16, 22	Summer/Autumn
Molluscs	Blue mussel	2	2, 9b	Summer/Autumn

* Green algae/seaweed is alternative sample type depending on availability at the sampling site.

Table 8-2. The Barsebäck NPP extended environmental programme every forth year.

	Sample types	**Number of samples**	**Sampling point**	**Sampling frequency Four year period**
Sediment		1	38	Quarterly
		8	30, 31, 33, 35, 37, 39, 40, 41	Once/year
Algae	Biofouling	2	1a, 7c	Monthly, Mars-November
	Bladderwrack	10	1, 7, 9b, 14, 15, 16, 17, 20, 22, 23	Once/year Summer/Autumn
Molluscs	Blue mussel	4	2, 9b, 21, 22	Once/year Summer/Autumn
Fish	European flounder*	3	9b, 17, 18	Once/year Summer/Autumn
	Atlantic/Baltic herring	1	18	Summer/Autumn
	Atlantic cod	1	7	Summer/Autumn

* European eelpout is alternative sample type depending on availability at the sampling site

Quality assurance of the sampling, analysis and evaluation is performed by site inspections by the SSM, by measurements of duplicated samples at the SSM laboratory and by participating in intercalibration measurements of the laboratories at the different sites.

Measurements of the samples are carried out by means of high resolution gamma spectrometry where a p-type High Purity Germanium detector (HPGe) is utilised. The activity levels are measured per unit mass of dry weight.

Today, 19 and 13 years after B1 and B2 ceased operations, the main anthropogenic gamma-emitting radionuclides detected in the environment are Co-60 and Cs-137 as well as naturally occurring radionuclides, mainly K-40. The most common radionuclide is Cs-137 which is mainly attributed to the Chernobyl accident and has thus caused increased levels in all environmental samples [40][39]. The Chernobyl accident is regarded as the main source of Cs-137 (82 %) in the Baltic Sea followed by the global fallout (14 %) and releases from nuclear fuel reprocessing plants (4 %) located outside of the Baltic Sea [40] and [41].

For sediment samples collected in the vicinity of the Barsebäck NPP, activity concentrations for Co-60 are below the MDA values (approximately 1 Bq/kg) and the Cs-137 values are in the range of 10 – 25 Bq/kg. Within the southern Baltic Sea, the highest Cs-137 activity concentrations in sediments (~200 -250 Bq/kg in the uppermost 2 cm sediment layer as of 2010) are found in the Gulf of Gdansk [41]. In that study, the lowest values are found in the Bornholm Basin (~ 50 Bq/kg in the uppermost sediment layer as above). In figures 8-2 and 8-3 examples of activity concentrations in sediments, collected in station 35 every fourth year as a part of the extended programme and seaweed collected in station 7 as a part of the basic programme, are presented. A decreasing long-term accumulation trend for both Co-60 and Cs-137 can be observed in figures 8-2 and 8-3.

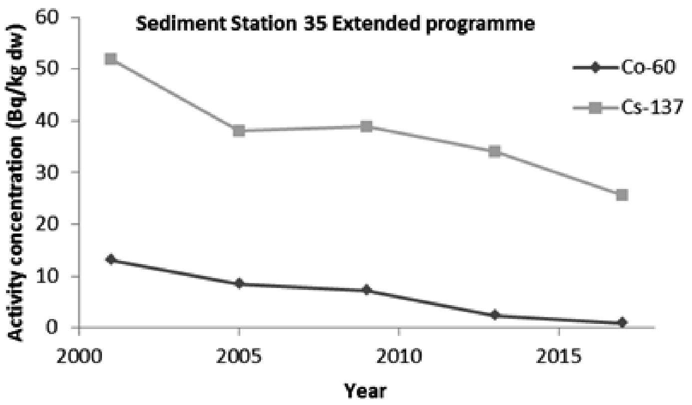


Figure 8-2. Concentrations of Co-60 and Cs-137 in sediment samples collected in station 35 (according to figure 8-1) over the years 2001 – 2017 as a part of the extended programme.

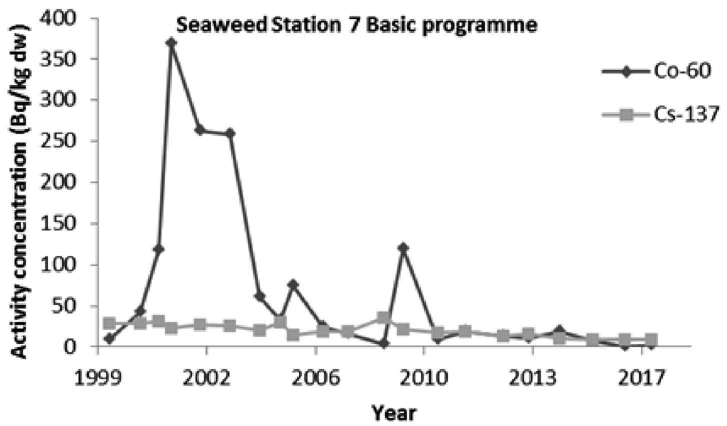


Figure 8-3. Concentrations of Co-60 and Cs-137 in seaweed samples collected in station 7 (according to figure 8-1) over the years 1999 – 2017 as a part of the basic programme.

Generally, the C&M operation at the Barsebäck NPP has a low impact on the environment from a radiological point of view, since the releases of radioactive substances to air and water are well below the specified limits (see chapter 0 and 4 in this report). The limits are set as an annual effective dose (0,1 mSv/year) from discharges to air and water to any individual in the reference group according to the regulation SSMFS 2008:23.

In the autumn of 2016 segmentation of the internal parts of the Unit 2 started. An environmental radiological impact was not observable, neither from segmentation of the internal parts or from the operation of the interim storage 1 where the internals are stored, during the 2017 environmental radiological monitoring where an extended programme was conducted [42].

During decommissioning the discharges will continue as long as the facility contains an activity inventory and based on the expected discharges to air and water described in chapter 0 and 4 of this report, it is judged that the activity concentration levels in the environment will be similar to those currently observed. The environmental radiological monitoring programme will be maintained during the decommissioning phase but regulated by the licence conditions for decommissioning [12].

8.3. Measurement of external dose rate

The Barsebäck NPP has during C&M operation an exemption [6] from section 22 in SSMFS 2008:23 which states that monitoring of gamma radiation shall be performed continuously in the vicinity of nuclear power reactors within each 30-degree sector on land at about 1 kilometre from the reactor. This exemption also applies to the decommissioning phase according to the license conditions for decommissioning [12]. However, area dosimetry at the Barsebäck site is performed deploying thermoluminescent dosimeters (TLD) at 6 monitoring positions, see figure 8-4 and table 8-3.

In general two TLDs are installed at every monitoring point at an elevation of 1,5 m above ground level. The TLDs are collected and analysed quarterly and the annual exposure is obtained by integrating the data for each quarter of the year.

Figure 8-5 shows the results for the monitoring points for the area dosimeters from 2007 to 2017.

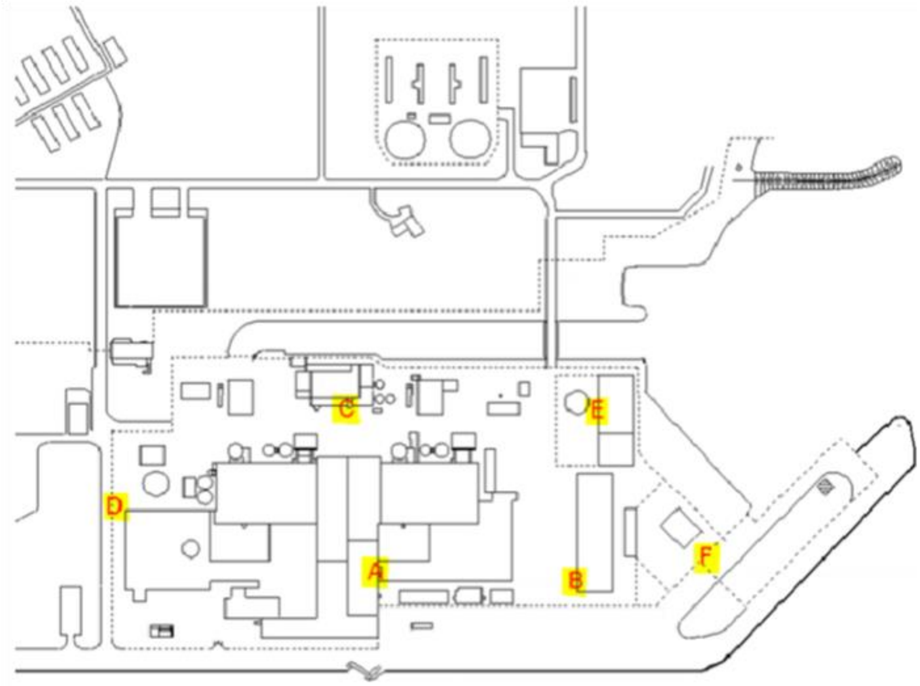


Figure 8-4. Positions of the area dosimeters within the Barsebäck site.

Table 8-3. Area dosimeter descriptions

Posi-tion	**Description**
A	Personnel entrance
B	Western corner
C	Waste building entrance 9
D	North corner
E	Entrance AB-storage facility
F	Interim storage facility

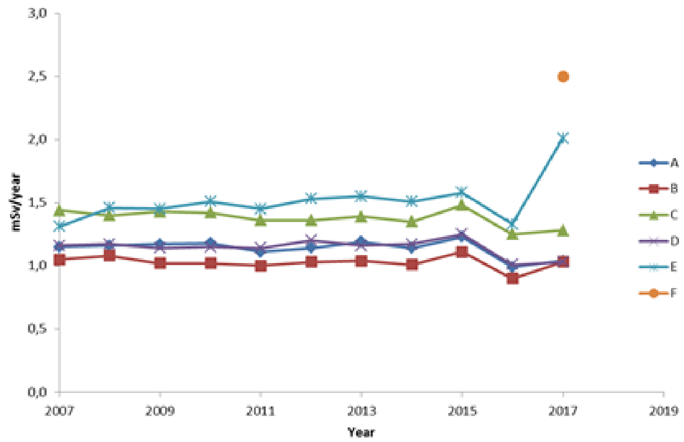


Figure 8-5. Positions of the area dosimeters within the Barsebäck site.

As shown, the obtained values are in the range of 1-1,5 mSv/year which corresponds to the natural background radiation levels. The dosimeter at position F was added to the measurements in connection with the commissioning of the interim waste storage facility were the reactor internal parts are stored. Elevated values corresponding to twice the background radiation levels, primary associated with transportation of the internals, are registered in that position. Another point that could be addressed is the dosimeter at position E where the elevated level during 2017 is due to the management of radioactive waste in that area.

The background levels are approximately a factor of 1E7 higher than the dose to the most exposed individual in the reference group for 2017. The dose contribution from the ongoing activities in the Barsebäck NPP is thus negligible compared to the natural background levels.

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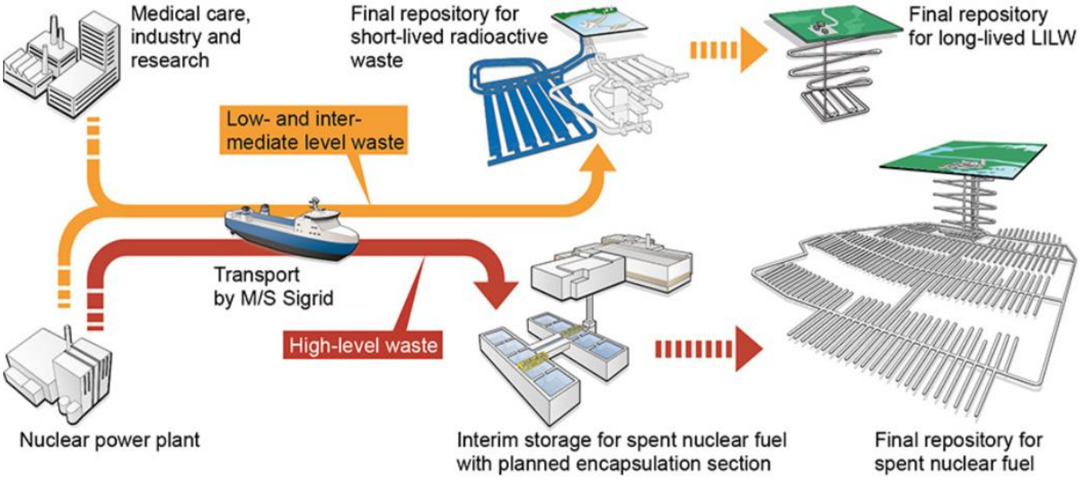
Appendices

Appendix 1 - Definitions and abbreviations used in this report

Acceptance criteria	Conditions to verify that a requirement is fulfilled
Barsebäck NPP	Barsebäck nuclear power plant B1 = Barsebäck unit 1, B2 = Barsebäck unit 2
BKAB	Barsebäck Kraft AB
C&M operation	Care & Maintenance operation. Care and Maintenance operation commenced when all nuclear fuel had been removed from the facility as well as all other adaptations have been completed. The duration of Care and Maintenance operation lasts until decommissioning is commences. Planning of decommissioning operation is included in the Care and Maintenance operation.
Clab	Central interim storage for spent nuclear fuel
Controlled area	Area inside the facility where personnel can be exposed to radiation or from which radioactive contamination can be spread to adjacent spaces.
D&D	Dismantling and demolition. Dismantling and demolition commence when the preparations for decommissioning are complete and when all permits for D&D have been issued.
Long-lived waste	Radioactive waste containing long-lived radionuclides and has a half-life greater than 30 years.
Low and intermediate level waste (LLW and ILW)	**Low level waste** Radioactive waste with an activity level low enough to not require shielding or cooling. **Intermediate level waste** Waste which is not as radioactive as spent nuclear fuel and does not require cooling when handled. The waste does require shielding when handled and is stored separated from the environment for several hundred years until the radioactive substances have decayed.

Neutron-induced waste	Components located close to the reactor core, within approximately 1 metre, and subjected to neutron bombardment.
OKG	Oskarshamns KraftGrupp, which operates the reactor O3 and is decommissioning O1 and O2.
PSAR	Preliminary safety analysis report
Representative individual	Representative real or hypothetical individual in the population who is expected to receive the maximum radiation dose from a radiation source.
SAR	Safety analysis report
SFL	Final repository for long-lived radioactive waste
SFR	Final repository for short-lived radioactive waste
Short-lived waste	Radioactive waste containing nuclides with short half-lives, less than 30 years.
SKB	Swedish nuclear fuel and waste management company
SMHI	Swedish Meteorological and Hydrological Institute
SNP	Sydkraft Nuclear Power
SSM	Radiation safety authority
SSMFS	Radiation safety authority’s regulations

Appendix 2 - The system for dealing with Swedish radioactive waste



A safe final repository system
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.

Nuclear power plants
There are three nuclear power plants with a total of eight reactors in operation in Sweden.

Hospitals, industry and research
Radioactive waste that has to be disposed of safely is also produced in hospitals and industry. This waste is low or intermediate level.

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 Nuclear Fuel (Clab)
Today all of the spent nuclear fuel produced by Swedish nuclear power stations so far, just over 5,000 tonnes, is in interim storage in Clab outside Oskarshamn. It is placed in storage pools located in rock vaults 25–30 metres 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 metres below sea level.

In 2014 SKB submitted an application to the authorities for a permit to extend the SFR primarily to make room for decommissioning waste, initially from the two reactors at Barsebäck that were closed down in 1999 and in 2005.

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. It will be deposited there in sealed copper canisters placed in rock vaults and surrounded by bentonite clay at a depth of 500 metres in the rock.

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. The canisters will be made of copper with inserts of nodular cast iron and will each contain about 2 tonnes of waste.

Final Repository for Long-lived Radioactive Waste (SFL)
SKB is also planning a final repository for long-lived radioactive waste, SFL. This project has not, however, progressed as far as the others.

Source: https://www.skb.se

Appendix 3 - Maximum expected doses to reference group from emissions to air from B1 (113 m)

This table presents the maximum expected doses to the reference group from emissions to air from B1 (113 m), shown for different age categories.

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Age 0-1 year [mSv]	0,0E+00	1,8E-07	1,0E-07	1,5E-07	1,1E-07	1,6E-07	8,7E-08	6,7E-08	3,4E-08	2,4E-08
Age 1-2 year [mSv]	0,0E+00	2,5E-07	1,4E-07	2,1E-07	1,5E-07	2,2E-07	1,3E-07	9,7E-08	5,0E-08	3,6E-08
Age 2-7 year [mSv]	0,0E+00	2,5E-07	1,4E-07	2,1E-07	1,5E-07	2,2E-07	1,3E-07	9,9E-08	5,1E-08	3,7E-08
Age 7-12 year [mSv]	0,0E+00	2,8E-07	1,7E-07	2,4E-07	1,7E-07	2,6E-07	1,5E-07	1,2E-07	6,2E-08	4,5E-08
Age 12-17 year [mSv]	0,0E+00	2,9E-07	1,7E-07	2,6E-07	1,9E-07	2,9E-07	1,7E-07	1,3E-07	7,0E-08	5,1E-08
Adults [mSv]	0,0E+00	2,0E-07	1,2E-07	1,7E-07	1,2E-07	1,9E-07	1,1E-07	8,3E-08	4,3E-08	3,1E-08

Appendix 4 - Maximum expected doses to reference group from emissions to air from B2 (113 m)

This table presents the maximum expected doses to the reference group from emissions to air from B2 (113 m), shown for different age categories.

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Age 0-1 year [mSv]	0,0E+00	8,7E-08	2,7E-07	1,3E-07	2,3E-07	9,1E-08	9,0E-08	5,6E-08	3,1E-08	1,4E-08
Age 1-2 year [mSv]	0,0E+00	1,1E-07	3,6E-07	1,7E-07	3,1E-07	1,2E-07	1,2E-07	7,5E-08	4,2E-08	1,8E-08
Age 2-7 year [mSv]	0,0E+00	1,1E-07	3,6E-07	1,7E-07	3,1E-07	1,2E-07	1,2E-07	7,5E-08	4,2E-08	1,8E-08
Age 7-12 year [mSv]	0,0E+00	1,2E-07	3,7E-07	1,8E-07	3,2E-07	1,3E-07	1,3E-07	8,0E-08	4,5E-08	2,0E-08
Age 12-17 year [mSv]	0,0E+00	1,2E-07	3,7E-07	1,8E-07	3,2E-07	1,2E-07	1,2E-07	7,9E-08	4,5E-08	2,0E-08
Adults [mSv]	0,0E+00	9,3E-08	2,9E-07	1,4E-07	2,5E-07	9,9E-08	9,8E-08	6,2E-08	3,5E-08	1,5E-08

Appendix 5 - Maximum expected doses to reference group from emissions to air from B1 + B2 (20 m)

This table presents the maximum expected doses to the reference group from emissions to air from B1+B2 (20 m), shown for different age categories.

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Age 0-1 year [mSv]	0,0E+00	0,0E+00	0,0E+00	0,0E+00	2,7E-07	2,0E-07	1,4E-07	3,0E-07	4,8E-07	8,2E-07
Age 1-2 year [mSv]	0,0E+00	0,0E+00	0,0E+00	0,0E+00	3,7E-07	2,7E-07	1,9E-07	4,1E-07	6,6E-07	1,1E-06
Age 2-7 year [mSv]	0,0E+00	0,0E+00	0,0E+00	0,0E+00	3,7E-07	2,7E-07	2,0E-07	4,1E-07	6,7E-07	1,2E-06
Age 7-12 year [mSv]	0,0E+00	0,0E+00	0,0E+00	0,0E+00	4,1E-07	2,9E-07	2,2E-07	4,6E-07	7,4E-07	1,3E-06
Age 12-17 year [mSv]	0,0E+00	0,0E+00	0,0E+00	0,0E+00	4,1E-07	3,0E-07	2,2E-07	4,7E-07	7,8E-07	1,4E-06
Adults [mSv]	0,0E+00	0,0E+00	0,0E+00	0,0E+00	3,2E-07	2,3E-07	1,7E-07	3,6E-07	5,8E-07	1,0E-06

Appendix 6 - Maximum expected doses to reference group from emissions to air from B1 + B2

This table presents the maximum expected doses to the reference group from emissions to air from B1+B2 (Total air), shown for different age categories.

	2018	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
Age 0-1 year [mSv]	0,0E+00	2,7E-07	3,8E-07	2,8E-07	6,1E-07	4,4E-07	3,2E-07	4,2E-07	5,4E-07	8,6E-07
Age 1-2 year [mSv]	0,0E+00	3,6E-07	5,0E-07	3,8E-07	8,3E-07	6,1E-07	4,4E-07	5,8E-07	7,5E-07	1,2E-06
Age 2-7 year [mSv]	0,0E+00	3,6E-07	5,0E-07	3,8E-07	8,3E-07	6,1E-07	4,4E-07	5,9E-07	7,6E-07	1,2E-06
Age 7-12 year [mSv]	0,0E+00	4,0E-07	5,4E-07	4,2E-07	9,0E-07	6,9E-07	4,9E-07	6,6E-07	8,5E-07	1,4E-06
Age 12-17 year [mSv]	0,0E+00	4,1E-07	5,4E-07	4,4E-07	9,2E-07	7,1E-07	5,1E-07	6,8E-07	8,9E-07	1,4E-06
Adults [mSv]	0,0E+00	3,0E-07	4,1E-07	3,2E-07	7,0E-07	5,2E-07	3,7E-07	5,0E-07	6,6E-07	1,1E-06

Appendix 7 - Maximum expected doses to reference group from emissions to water from B1+B2

This table presents the maximum expected doses to the reference group from emissions to water from B1+B2, shown for different age categories.

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Age 0-1 year [mSv]	0,0E+00	1,7E-09	2,3E-09	1,7E-09	1,4E-09	1,0E-09	7,8E-10	6,0E-10	4,7E-10	7,1E-10
Age 1-2 year [mSv]	0,0E+00	7,0E-07	1,0E-06	7,7E-07	6,9E-07	5,2E-07	4,1E-07	3,3E-07	2,7E-07	4,2E-07
Age 2-7 year [mSv]	0,0E+00	7,0E-07	1,0E-06	7,7E-07	6,9E-07	5,3E-07	4,1E-07	3,4E-07	2,8E-07	4,3E-07
Age 7-12 year [mSv]	0,0E+00	9,3E-07	1,4E-06	1,0E-06	9,5E-07	7,3E-07	5,8E-07	4,8E-07	3,9E-07	6,2E-07
Age 12-17 year [mSv]	0,0E+00	1,2E-06	1,8E-06	1,4E-06	1,3E-06	9,7E-07	7,7E-07	6,4E-07	5,3E-07	8,4E-07
Adults [mSv]	0,0E+00	9,8E-07	1,5E-06	1,1E-06	1,1E-06	8,2E-07	6,6E-07	5,5E-07	4,6E-07	7,3E-07

Appendix 8 - Maximum expected doses to reference group from emissions to water and air from B1 + B2

This table presents the maximum expected doses to the reference group from emissions to water and air from B1+B2, shown for different age categories.

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Age 0-1 year [mSv]	0,0E+00	2,7E-07	3,8E-07	2,8E-07	6,1E-07	4,4E-07	3,2E-07	4,2E-07	5,4E-07	8,6E-07
Age 1-2 year [mSv]	0,0E+00	1,1E-06	1,5E-06	1,1E-06	1,5E-06	1,1E-06	8,4E-07	9,1E-07	1,0E-06	1,6E-06
Age 2-7 year [mSv]	0,0E+00	1,1E-06	1,5E-06	1,2E-06	1,5E-06	1,1E-06	8,6E-07	9,3E-07	1,0E-06	1,6E-06
Age 7-12 year [mSv]	0,0E+00	1,3E-06	1,9E-06	1,5E-06	1,9E-06	1,4E-06	1,1E-06	1,1E-06	1,2E-06	2,0E-06
Age 12-17 year [mSv]	0,0E+00	1,6E-06	2,3E-06	1,8E-06	2,2E-06	1,7E-06	1,3E-06	1,3E-06	1,4E-06	2,3E-06
Adults [mSv]	0,0E+00	1,3E-06	1,9E-06	1,5E-06	1,8E-06	1,3E-06	1,0E-06	1,1E-06	1,1E-06	1,8E-06

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The Swedish Radiation Safety Authority has a comprehensive responsibility to ensure that society is safe from the effects of radiation. The Authority works to achieve radiation safety in a number of areas: nuclear power, medical care as well as commercial products and services. The Authority also works to achieve protection from natural radiation and to increase the level of radiation safety internationally.

The Swedish Radiation Safety Authority works proactively and preventively to protect people and the environment from the harmful effects of radiation, now and in the future. The Authority issues regulations and supervises compliance, while also supporting research, providing training and information, and issuing advice. Often, activities involving radiation require licences issued by the Authority. The Swedish Radiation Safety Authority maintains emergency preparedness around the clock with the aim of limiting the aftermath of radiation accidents and the unintentional spreading of radioactive substances. The Authority participates in international co-operation in order to promote radiation safety and finances projects aiming to raise the level of radiation safety in certain Eastern European countries.

The Authority reports to the Ministry of the Environment and has around 300 employees with competencies in the fields of engineering, natural and behavioural sciences, law, economics and communications. We have received quality, environmental and working environment certification.

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