Strål
säkerhets
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Swedish Radiation Safety Authority

Report

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

Expanded operations within Cyclife Sweden AB

2024:09

Date: May 2024
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SSM perspective

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

Abstract

Cyclife Sweden AB (Cyclife) operates facilities that manages and treats radioactive waste, mainly from the nuclear industry, in order to recycle metals and volume reduce wastes that can either be treated by melting, incineration or pyrolysis.

This document describes the plans of expansion of operations (from 5 600 tonnes to 10 600 tonnes) within Cyclife Sweden AB, situated on the Studsvik Tech Park in Sweden. The purpose of the document is to serve as information for the European Commission, and to fulfil the requirements of Article 37 of the Euratom Treaty. According to Article 37, each Member State shall provide the Commission with such general data as will make it possible to determine whether the planned activities are liable to result in radioactive contamination of another Member State.

The plans of expansion within Cyclife Sweden AB are considered a modification of plan for the disposal of radioactive waste on which no opinion has already been given under the terms of Article 37. Therefore the general data is submitted according to Annex VI in the Commission Recommendation of 11 October 2010 on the application of Article 37 of the Euratom Treaty.

This document also presents an estimation of the maximum expected emissions of radioactivity to air and water during operation of 10 600 tonnes. This also includes a dose evaluation to explain the impact on a reference population living in the vicinity to the facilities.

During normal operation after the increase of production levels the expected maximum dose exposure for an individual is estimated to be 0.44 µSv (total: air and water), this compared to today's level of 0.03 µSv, an increase of approximately 0.42 µSv. This means that the maximum exposure for an adult, child, or an infant in the vicinity of the facilities are expected to be far below 10 µSv per year for both emissions from air and water during normal conditions. Any unexpected emissions are also estimated to be below 1 mSv per year for an adult, child, or an infant in the vicinity of the facilities and therefore do not pose any risk to the neighbouring Member States.

Content

Introduction

Cyclife Sweden AB (Cyclife) operates facilities that manages and treats radioactive waste, mainly from the nuclear industry, in order to recycle metals and volume reduce wastes that can either be treated by melting, incineration or pyrolysis. Cyclife also have a service that removes radioactive sources and other radioactive materials originating from the non-nuclear part of the Swedish society, such as schools and research institutes. The operations are supported by an Analytical laboratory that performs analyses for determining their radioactive content. The Analytical laboratory also offers services to customers outside Cyclife.

In order to increase the possibilities to treat more complex material, Cyclife has got permission within the existing environmental permits to build an Annex to the metals treatment facility SMA. When this expansion (SMA Annex) is operational the available production will increase from todays 5 600 tonnes to 10 000 tonnes in the melting facilities and 600 tonnes in incineration and pyrolysis. The SMA Annex is planned to be commissioned in 2023 – 2025 and operational in 2025.

The location of SMA Annex is within Studsvik Tech Park (STP), approximately 20 km from the city Nyköping. The land for the SMA Annex was acquired from Studsvik Nuclear AB's (SNAB's) property Hånö 1:9. Figure1 shows STP with Cyclife property boundaries, the location of SMA and SMA Annex as well as Cyclife's other buildings, in blue.

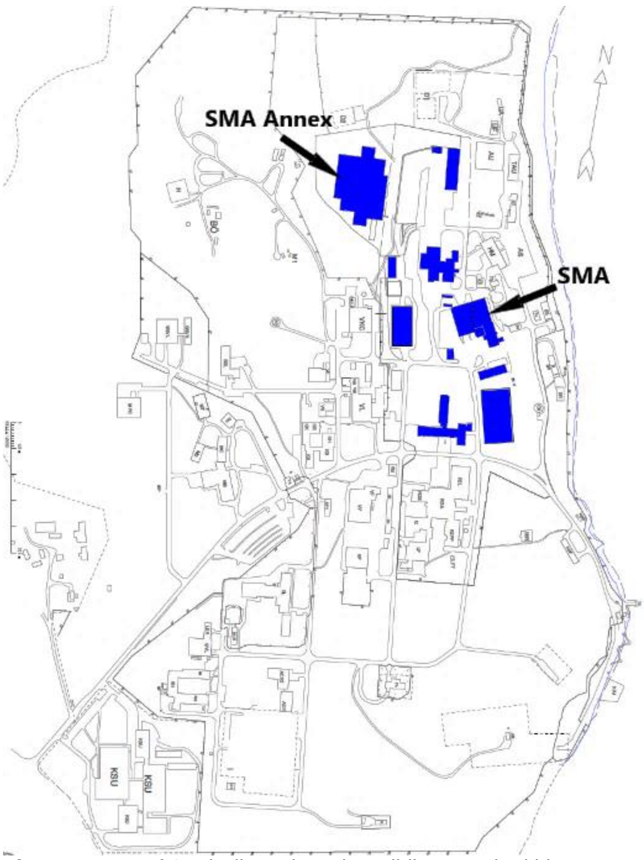

Figure 1. Map of Studsvik Tech Park. Buildings marked blue are property of Cyclife Sweden AB [1].

The SMA Annex is an extension of SMA and will have the same operational possibilities as well as treatment of large components such as Steam Generators and boilers with higher weights and dose rates than is possible to treat today in SMA.

Treatment of metals has a few main operations: segmentation, decontamination and melting the metal after which clearance from regulatory control and recycling of the metal is the preferred option. Segmentation means that the material is size reduced in order to fit the next step in the process. During decontamination, the main part of the radioactivity from the surface is removed. Consequently, when the metal is melted, the residual radioactive content is usually below regulatory clearance limits and the metal can be released from regulatory control and recycled into the conventional industry.

Nuclear facilities in Sweden must comply with the Environmental Code (1998:808), the Swedish Act of Nuclear Activities (1984:3) and the Radiation Protection Act (2018:396) as well as the regulations that follow these. SMA Annex is included in the SMA permit as long as the production is not higher than what is given in the environmental permit. Cyclife plans to apply to the Environmental Court to increase the total production for melting and incineration/pyrolysis to 10 000 + 600 tonnes per year compared to todays 5 000 + 600 tonnes per year. Therefore, the general data submitted in this report contains information of all operating facilities within Cyclife Sweden AB.

The plans for increasing the total production within Cyclife Sweden AB are considered a modification of plan for the disposal of radioactive waste on which no opinion has already been given under the terms of Article 37. According to the Commission Recommendation of 11 October 2010 on the application of Article 37 of the Euratom Treaty (2010/635/Euratom) the submission of general data should then be governed by the conditions in point 5 of the recommendation. Considering that a new authorisation is required, according to the condition 5 (d) in the recommendation, the general data is submitted in accordance to Annex VI.

All nuclear activities at STP are limited by regulations of 0.1 mSv per year to a hypothetical group for the total emissions to air and water [2] [3]. It means that the effect of the emissions must not give a radiation dose of more than 0.1 mSv per year to any person in the public. Radioactive emissions from STP are well below the regulated value and are reported annually to the Swedish Radiation Safety Authority (SSM).

The maximum exposure for adults, children, and infants in the vicinity of the facilities from emissions release during normal conditions are expected to be far below 10 µSv per year. Due to the low dose to a reference group during normal conditions and that there are no exceptional exposure pathways a dose evaluation is not required for other EU member states.

The assessed maximum exposure levels from a hypothetical radiological accident to adults, in the vicinity of the facilities, are below 1 mSv. Furthermore, given the absence of exceptional exposure pathways, a dose evaluation is not required for other EU member states.

1. The site and its surroundings

1.1. Geographical, topographical and geological features, land use and distances to neighbour Member States

Cyclife Sweden AB (Cyclife) is located at site Studsvik Tech Park (STP) at the east coast of Sweden within the Nyköping municipality, County of Södermanland, see Figure 2 and Figure 3. The coordinates for Cyclife are 58°46'N, 17°23'E.

Figure 2. The location of Cyclife Sweden AB in Sweden [4].

Figure 3. The location of Cyclife Sweden AB at Studsvik Tech Park [4].

The buildings in which Cyclife operates were originally built in the 1950 – 1960ies and has since been rebuilt, upgraded, and extended. The location of the STP site was chosen considering the site favourable conditions such as the bay Tvären which was used as a cooling water reservoir for the research reactors operating on STP (since then decommissioned). The area was and still is a sparsely populated area. A small residential area is situated immediately south of the site. Three other residential areas are situated approximately 1.5 kilometres from STP.

In the immediate surroundings of STP there are different nature reserves and Natura 2000[1] sites and the archipelago is considered as an area of high natural value. According to the County Administrative Board of Södermanland the coast and the archipelago are frequently visited during the summer.

The bedrock of the STP area predominantly consists of gneiss granite, sedimentary gneiss covered by sand, moraine, and gravel [5] [6] as shown in Figure 4.

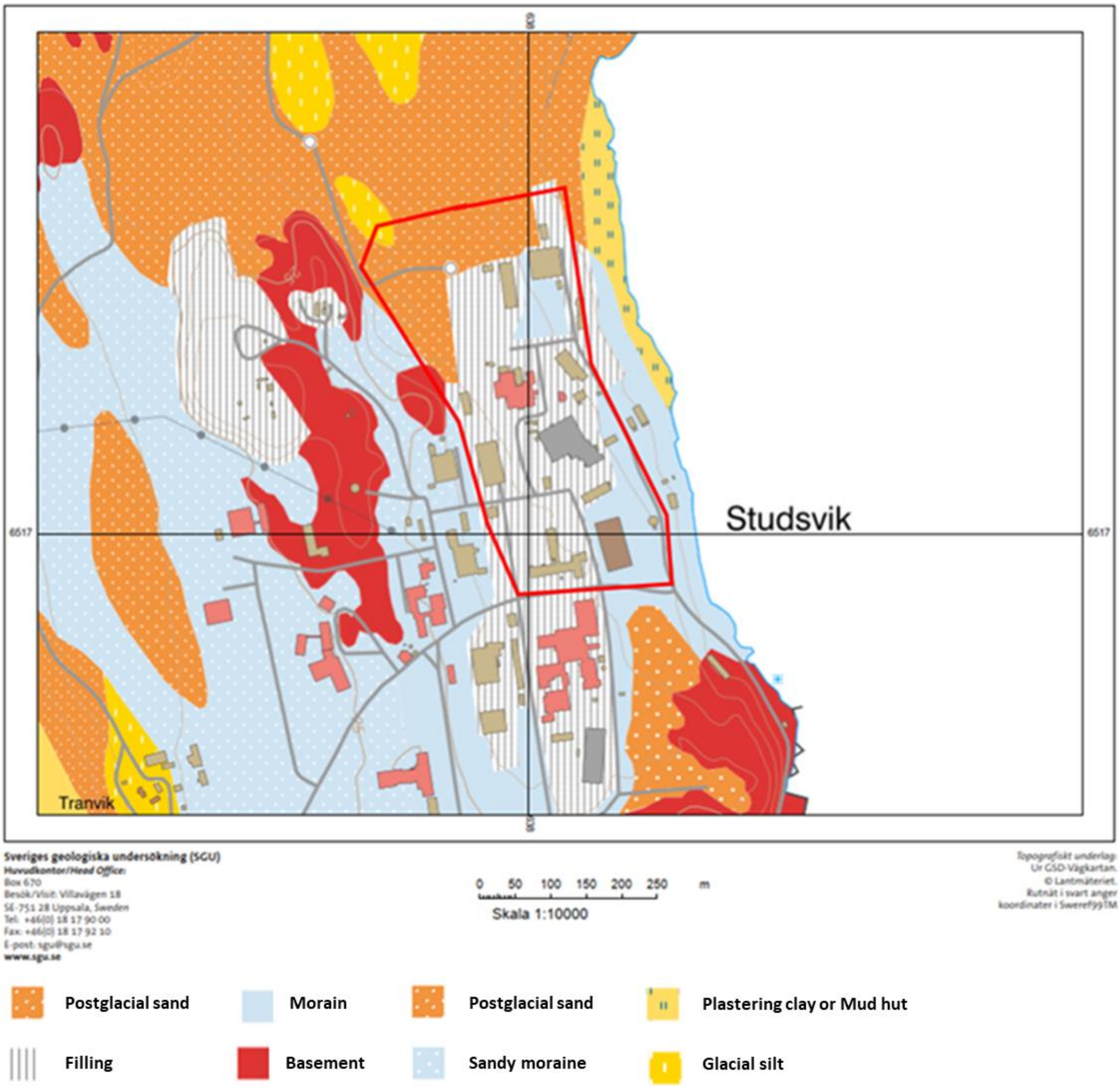

Figure 4. The map shows the soil types defined by SGU. Approximate operational area is marked with a red line [6].

Two other companies, AB Svafo (Svafo) and Studsvik Nuclear AB (SNAB) own and operate nuclear installations at STP, see Figure 5 for locations, which also have releases to the environment.

[1] Natura 2000 is a network of nature protection areas within the territory of EU.

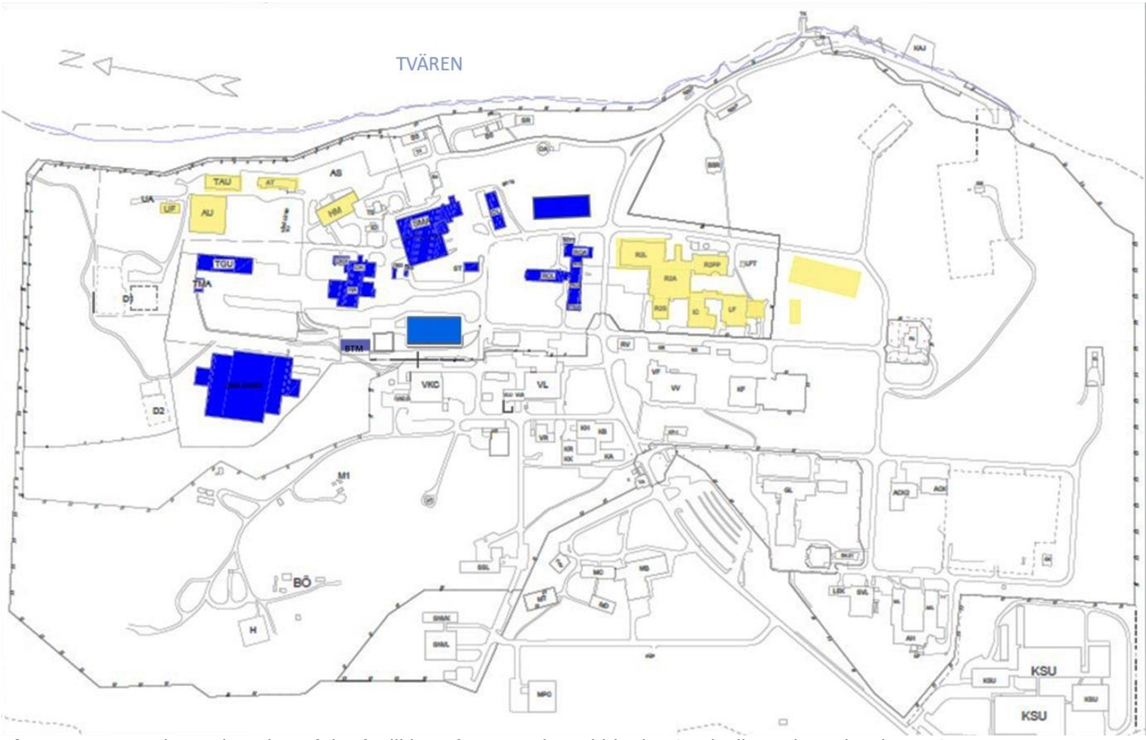

Figure 5. Approximate location of the facilities of companies within the Studsvik Tech Park. Blue = Cyclife Sweden AB, Yellow = AB Svafo and White = Studsvik Nuclear AB.

Neighbour Member States are shown in Figure 6. Distanced to neighbour Member State borders included the closest cities in the nearest Member States are listed in Table 1. Mariehamn, situated on the Åland Islands, a part of Finland, is the nearest city in a Neighbour Member state. Mariehamn is located about 200 km northeast from STP.

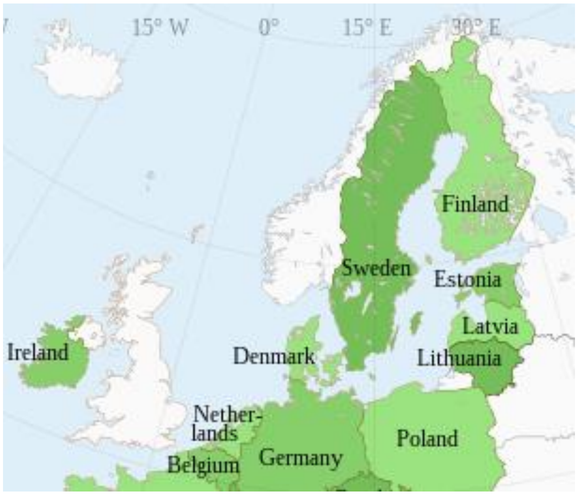

Figure 6. Neighbour Member States (ref. Wikimedia, 2023).

Table 1. Approximate distance to borders and urban areas in the nearest Member States. (ref. Google maps and Wikipedia, 2023)

State	Distance to border from Studsvik Tech Park (km)	Nearest city/urban area in Neighbour Member State	Distance to nearest city from Studsvik Tech Park (km)	Population in nearest city
Finland (Åland)	400 (200)	Mariehamn	200	11 000
Latvia	280	Ventspils	280	36 000
Estonia	300	Kuressaare	300	13 000
Lithuania	360	Klaipeda	400	160 000
Denmark	400	Copenhagen region	440	1 900 000
Poland	450	Gdynia-Sopot-Gdansk	480	750 000
Germany	520	Sassnitz	520	9 500

1.2. Hydrology

In the vicinity of STP there are both lakes and the Baltic Sea which together with the groundwater gives the hydrology baseline for the site.

The groundwater at STP drains eastwards to the bay Tvären, which is a part of the Baltic Sea. Tvären has an area on 18 km^2. The deepest point of Tvären is 80 meters. Tvären is delimited from the open Baltic Sea, by thresholds with no greater depth than 10 meters [7]. The water exchange rate of Tvären is approximately 7.3 km^3/year [8].

Groundwater levels in the area are at their highest in the spring after winter rainfalls and snowmelt, however, there are large variations between the years and seasons according to the authority Geological Survey of Sweden (SGU). The groundwater levels are not considered to affect the safety of the facilities and no penetration of groundwater into the buildings has been found so far. Heavy rainfall during a short period of time could cause flooding in the facilities, if such an event should occur the facilities are put in so-called safe mode until any risks are eliminated [9]. There are no rivers or streams flowing through the STP.

The Baltic Sea has no noticeable permanent surface water currents and the freshwater from land moves like a thin layer over the brackish sea water. The currents are then turning to the right due to the rotation of the Earth [10]. The fresh water and the sea water are gradually mixed and provides a slow coastal current south along the Swedish coast [10], see Figure 7.

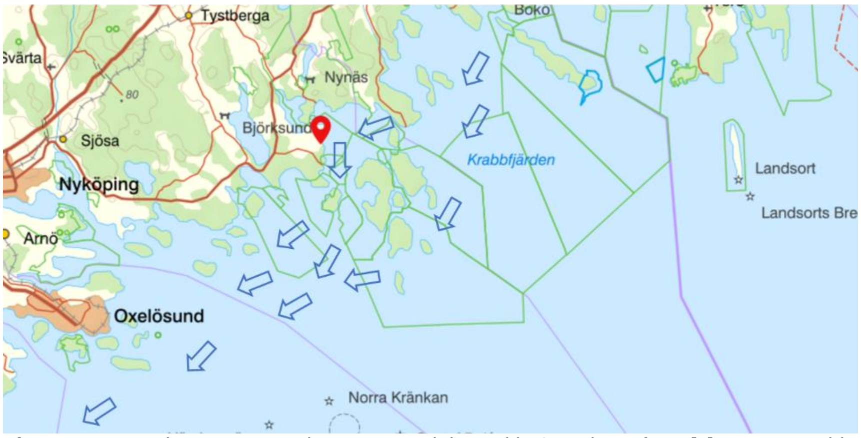

Figure 7. Approximate currents in Tvären and the Baltic Sea. (Map from [4], currents added by the author.)

Cyclife's facilities are located approximately 10 to 16 meters over the sea level [4]. The highest measured water level in the immediate sea area (Landsort) was measured in 1983 and was then +0.95m [9]. According to the Swedish Meteorological and Hydrological Institute (SMHI) the maximum wave height in the middle of the Baltic Sea is about 10 meters. The surrounding archipelago around Tvären limits the passage of the waves and the wave height is thus lower in Tvären than in the Baltic Sea.

The future mean sea water level, year 2050 and year 2100, along the coast, within the area, is expected to be at a maximum (median) of 30 cm RH 2000[2] respectively 70 cm RH 2000[2] (likely scenarios) [11]. The future sea water levels are not expected to have an impact on the facilities based on their locations in relation to the Sea.

1.3. Meteorology

Winds from southwest are predominating in the area as shown in Figure 8 and in an event of discharge of radioactive emissions the predominant plume direction is north-east of the site [12]. In the winter, northwest winds are common (December to February). The average precipitation is 650 mm/y with an average intensity of 0.5 mm/h and the average temperature is 6.4°C [13] for the STP. The proximity to the Baltic Sea causes a smoothing effect of temperature and extreme temperatures are not common at STP. Gust of wind can exceed the averages with an increased risk of falling trees and flying objects. Extreme weather[3] is rare in Sweden and along the Swedish east coast and such at STP. According to SMHI, the possibility for extreme weather will be more common in the future. An increase of rainfall in the climate scenarios also means stronger rainfall extremes, both on short time scales in the form of torrential rain and rainfalls over longer periods [14]. Heavy rainfall for a short period of time can cause flooding in the facilities, but the facilities will be put in a safe mode manually if water ingress occurs. In terms of future temperatures, a milder and warmer climate predicts lower temperatures during winters and hotter summers [14]. However, high/low outdoor temperatures are not considered to affect the

[2] The Swedish Kingdom's Height System 2000, RH 2000, is Sweden's national height system, which became official in 2005.
[3] E.g. storms, tornados, ice storms and heavy rainfall

safety of the facilities [15]. Changes in winds and storms are not something that can be clearly seen in calculated climate scenarios, according to SMHI [14].

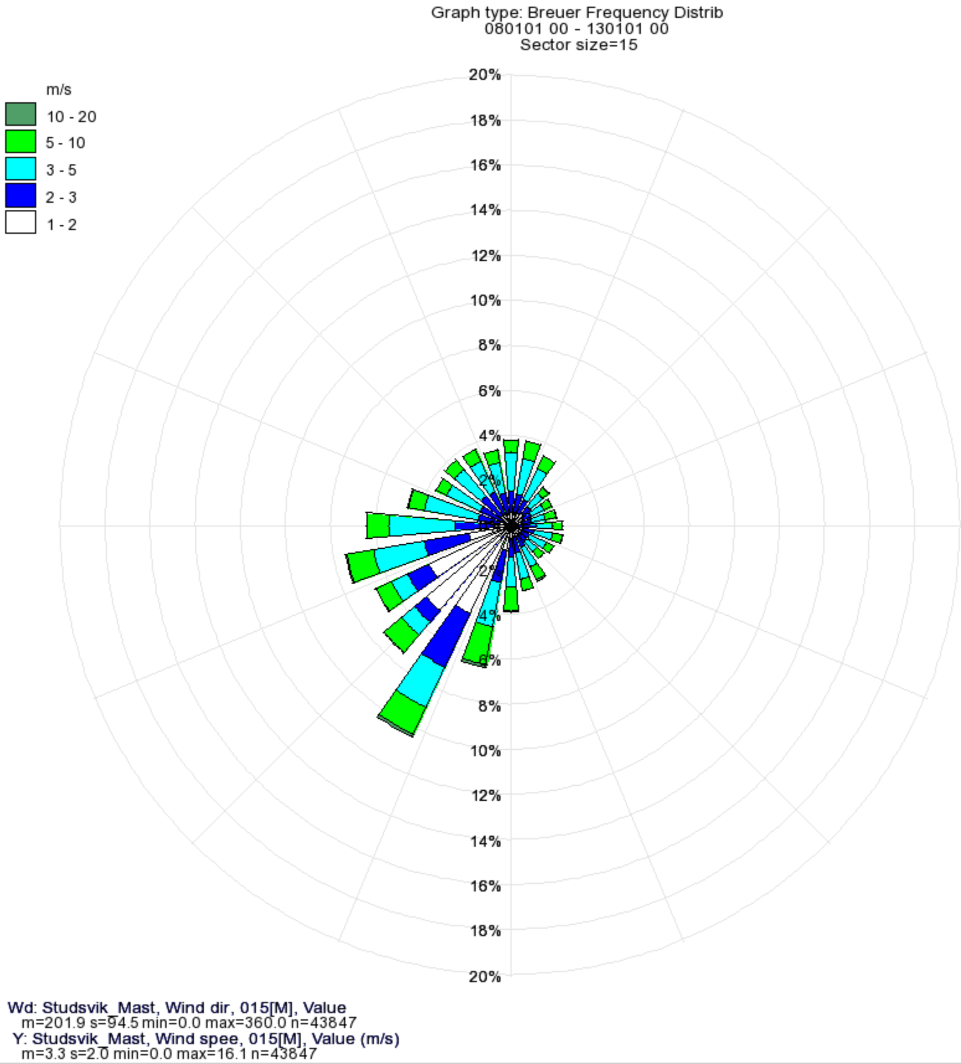

Figure 8. Meteorological data from the Studsvik Tech Park mast (approx. 20 meters over local ground) combined with Mesan data, where measurements are missing, in form of a wind rose [12].

1.4. Natural resources and foodstuffs

The STP provides its own freshwater by purifying water from the lake Trobbofjärden, located northwest from STP. The water purification plant is operated by Studsvik Nuclear AB and has a capacity of 20 m^3/h [9]. The surrounding residential areas within 2 kilometres from STP uses groundwater as drinking water etc from own wells. Neighbouring Member States are not impacted by groundwater or surface water from the STP.

The cropland surrounding STP mainly consists of smaller farms with high proportion of pastureland as shown in Figure 9. The inland area is more used for agricultural landscape and hunting. Commercial fishing occurs to a small extent in the near surroundings in the Baltic Sea and Tvären.

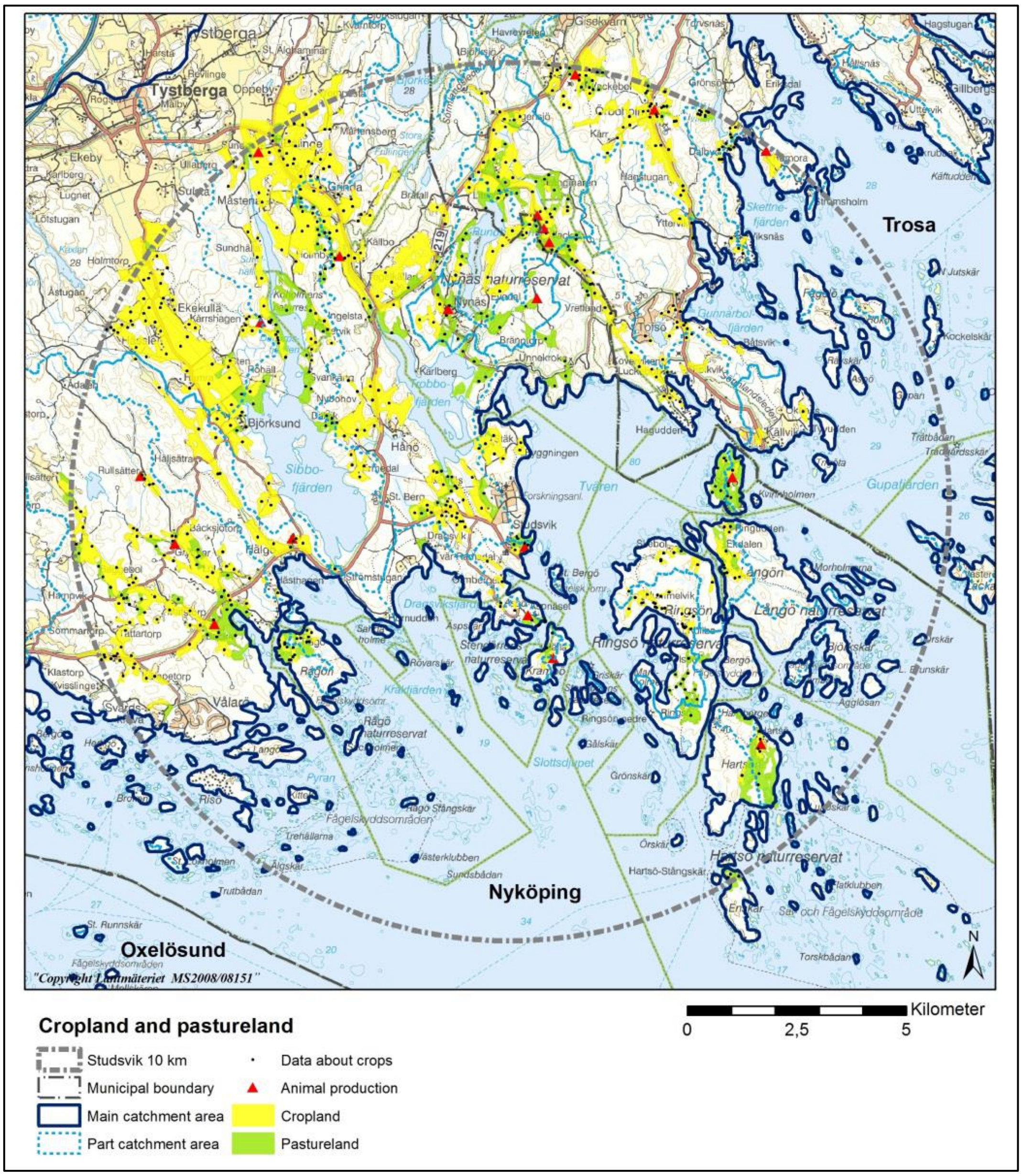

Figure 9. Agricultural activities within ten-kilometer radius from Studsvik Tech Park [12].

Table 2 compares the acreage for production used for crops in Nyköping Municipality, the County of Södermanland and Sweden. All data is from the Swedish Board of Agriculture's website for statistics [16].

Table 2. Acreage of crops produced in Sweden 2022: Nyköping and Södermanland compared with Sweden overall [16].

Crop	*Areal in hectares*		
	Sweden	**Södermanland**	**Nyköping**
Grain included: wheat, barley oats	962 454	54 135	12 404
Leguminous plants[4]	54 351	1 838	411
Grassland and green fodder plants[5]	1 132 239	48 111	11 704
Potatoes	23 409	38	5
Sugar beet	29 296	None	None
Rapeseed and colza	127 502	6 200	1 922
Other plants[6]	35 221	2 184	497
Resting cropland and unspecified cropland	173 474	10 475	2 267
Total cropland[7]	**2 537 946**	**122 981**	**29 210**
Percentage of Sweden overall	100%	4.85%	1.15%

Table 3 compares livestock in Nyköping Municipality, County of Södermanland and Sweden for the years 2020 and 2022. All data is from the Swedish Board of Agriculture's website for statistics [16].

Table 3. Quantities of livestock in Sweden 2020 and 2022: Nyköping and Södermanland compared with Sweden overall [16].

Livestock	**Sweden**		**Södermanland**		**Nyköping**	
	2020	**2022**	**2020**	**2022**	**2020**	**2022**
Cattle	1 452 982	1 449 316	41 505	42 170	7 377	Data not availa-ble
Sheep	501 153	509 937	19 618	19 394	2 387	
Pigs	1 367 755	1 392 944	54 433	55 052	1 792	
Poultry	35 152 848	34 298 022	3 744 146	3 069 344	697 838	
Total live-stock	**38 474 738**	**37 650 219**	**3 859 702**	**3 185 960**	**709 394**	-
Percentage of Sweden overall	100%	100%	10.0%	8.5%	1.8%	-

[4] Leguminous plants consist of peas and field beans, etc., canneries and brown beans.
[5] Grassland and green fodder plants include maize, green fodder, as well as mowing and grazing grassland.
[6] Seed ley, linseed, energy forest, garden plants and all other small field crops that are not included in the above re-port.
[7] Included unspecified crop land and unused cropland.

72% of Sweden's total exports value 2021 of agricultural goods and food went to countries within the EU and the largest markets for these goods were Norway, Denmark, Poland, France, Finland, Germany, Spain, the Netherlands, Italy, and the United Kingdom.

In 2021, fish, crustaceans and molluscs accounted for 40.2 % of the total of Swedish export value of agricultural goods and food. Meat and meat products accounted solely for 2.3 %, grains goods were at 9.5 % and dairy products and eggs at 4.6% [17]. Fishing in the Baltic Sea is extensive and done by several member states.

1.5. Other activities in the vicinity of the site

At STP there are two other companies that holds licences for operation of nuclear facilities:

- Studsvik Nuclear AB (SNAB) is engaged in fuel and material testing. SNAB also operates the overall infrastructure of heating, water, and sewage systems for STP.
- AB Svafo (Svafo) is decommissioning nuclear facilities and handling legacy nuclear waste from the early Swedish nuclear research.

The companies within STP (Cyclife, SNAB, Svafo) collaborates in several areas such as waste treatment, intermediate storage of waste, physical protection of STP and resources in the event of breakdowns and accidents. There are different agreements and cooperation forums established between Cyclife, SNAB and Svafo to ensure safe operations within STP. Figure 5 (under section 1.1) shows the approximate location of the facilities of companies within the Studsvik Tech Park.

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

2. The installation

The basic requirement for the construction of the facilities is to protect personnel from doses but also the environment and society from radioactive emissions. Every facility and each part of the facility has its own barriers and defence-in-depths to maintain safe operation of the facility.

The building for each facility is a barrier and the different parts of the building have external and internal barriers. External barriers are external walls, gates/doors, windows, roofs and floors. Internal barriers are interior walls and gates/doors within the facility. Within the Incineration and decontamination facility (HA/DK) and the Pyrolysis facility (Pyrolysis), the process equipment is defined as a set of internal barriers to protect personnel from radioactivity. The buildings are not completely gas-proof, but the ventilation system guarantees under-pressure.

2.1. Main features of the installation

The operations within Cyclife are largely to reduce the burden on the environment caused by radioactive waste [18]. Cyclife has several different facilities at STP for volume reduction, measurements for clearance, recycling, and characterization of radioactive waste:

- Metal treatment facility (SMA), for treatment of metallic radioactive waste by decontamination, segmentation and melting,
- Incineration and decontamination facility (HA/DK), for treatment of radioactive waste in the form of combustible solid waste and liquids/oils, for decontamination and for measurements for clearance,
- Pyrolysis facility (Pyrolysis) for treatment of combustible uranium-contaminated operational waste from customers in nuclear-fuel production,
- Non-Nuclear waste facility (IKA) for treatment of radioactive waste, sources, and other radioactive material from e.g., hospitals, are intermediate stored awaiting final disposal,
- Analytical laboratory (Analytical lab) where samples are analysed for determination of radioactivity content in different materials. Radioactivity measurements on environmental samples to determine releases from STP are also performed within Analytical lab.
- Interim storage, for low and intermediate-level radioactive waste waiting for return to customer, waiting for treatment or waiting for final disposal.

An additional metal treatment facility (SMA Annex) is under construction and is estimated to be in operation in 2025. It is within SMA Annex that the main increase in production will take place.

The current environmental permit [19] allows 5 000 tons per year for melting, of which a maximum of 1 500 tons per year may be aluminium, brass and copper, and a maximum of 1 000 tons per year may be lead. The melting process is preceded by decontamination and cutting.

The current environmental permit [20] for incineration and pyrolysis [21] allows to process (incinerate) 600 tonnes per year which 100 tonnes through pyrolysis.

In addition to melting, incineration and pyrolysis, waste is treated via direct decontamination and clearance. Since the current melting/incineration permits are given by weight, volume is not a limiting factor. Storage capacity on STP, further described in section 2.1.5, may be the only limiting factor based on volume.

For incoming material/waste for treatment there is a Waste Acceptance Criteria (WAC) in which limitation are set on the type of material and activities that can be processed within the facilities. WAC contains, among other things, Dose rate restrictions and Contamination restrictions.

2.1.1. SMA

SMA has been in operation since 1987. Within the facility radioactively contaminated metals primarily from the nuclear industry are decontaminated and volume-reduced by melting, Figure 10 and Figure 11.

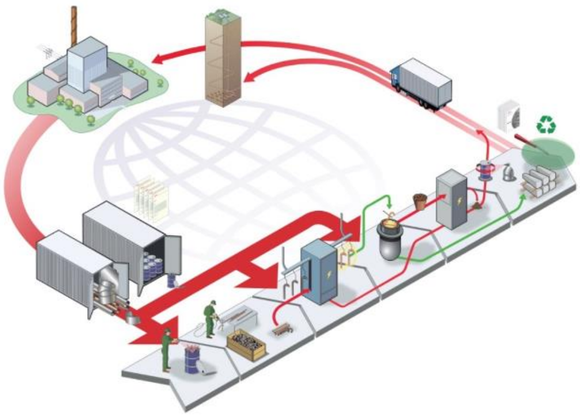

Figure 10. Sketch of the activities within SMA [22].

Figure 11. Radioactive scrap metal volume reduced by melting within the metal treatment facility SMA [18].

The treatment process leads to volume reduction of waste for disposal. The aim is that as much material as possible can be a subject for clearance and then be used for recycling of metals such as carbon steel, stainless steel, aluminium, copper etc. The dose rate in the facility varies with the incoming waste for treatment. Materials and components that are to be treated in SMA must follow Cyclife's WAC for Melting Services. The Dose rate restrictions are <0.2 mSv/h for Surface dose (D_0), were smaller fractions of "hot spots" up to maximum 0.5 mSv/h are allowed after acceptance from Cyclife. Dose rate at 1 m (D_1) are limited to <0.1 mSv/h. For treatment of metallic scrap and large components with specific activity levels above guidelines in WAC, an acceptance must be acquired by Cyclife for each specific case.

The SMA facility is divided into different halls as shown in Figure 12 e.g. melting hall, segmentation hall, cutting hall and blasting hall. Within the segmentation and cutting hall larger items and components are segmented to fit the machinery for further processing by blasting and melting.

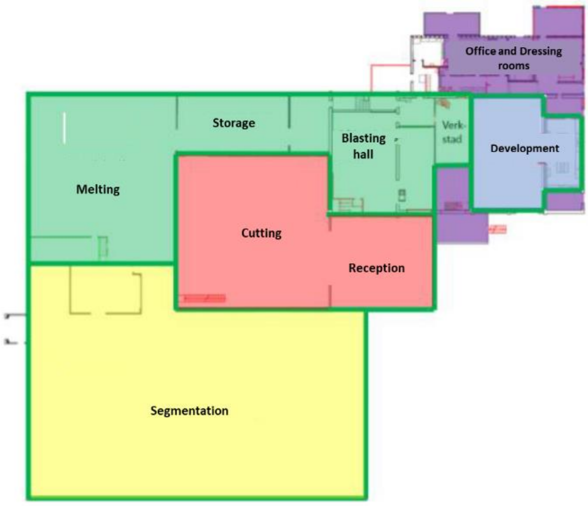

Figure 12. Plan sketch of the metal treatment facility SMA [9].

2.1.2. The additional metal treatment facility (SMA Annex)

SMA Annex, Figure 13, is under construction and is planned to be put in operation during the year 2025. SMA Annex will primarily be designed for the treatment of steam generators and large components and is going to be a complement to the existing metal treatment facility SMA. The main processes are to be decontamination, segmentation and melting such as in SMA. The total activity that allows in the SMA Annex is 9.27 TBq and the dose restriction are the same as for SMA, described under section 2.1.1 above.

In 2023, the County Administrative Board approved Cyclife to erect SMA Annex within the current environmental permit.

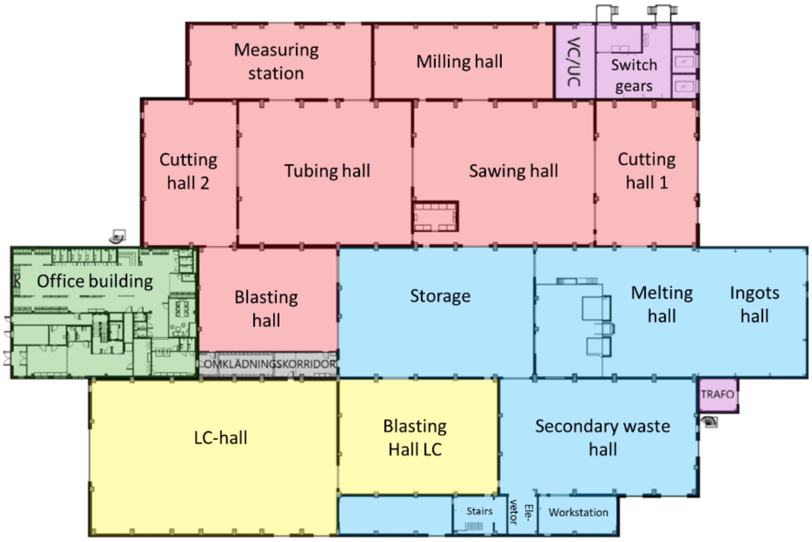

Figure 13. Plan sketch of SMA Annex [1].

2.1.3. HA/DK and Pyrolysis

The decontamination Hall (DK) was built in 1961 and located directly adjacent to the HA-building (HA) which was built in 1974 and the most recent addition is the building for the pyrolysis plant built in 2011, see Figure 14.

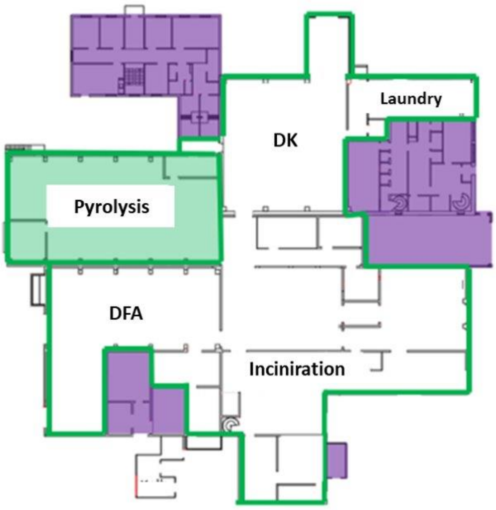

Figure 14. Plan sketch over facility HA/DK (ref. Cyclife management system)

Within the building complex of HA/DK/Pyrolysis the following treatment processes takes place:

- Incineration of radioactive waste in form of combustible solid waste and liquids/oils, see Figure 15,
- Decontamination and measurements for clearance, DFA-process,
- Pyrolysis of combustible uranium-contaminated operational waste from customers in nuclear-fuel production.

Additional operations within the facility are:

- Gamma measurements of secondary waste[8]
- Crushing of slag from the melting facility
- Laundry of protective clothing from STP

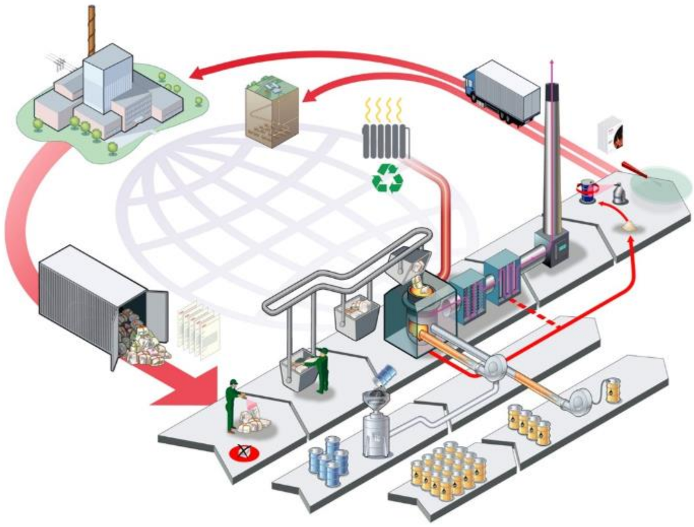

Figure 15. Sketch of the activities within Incineration facility HA [22].

2.1.4. Non-nuclear waste facility (IKA) and Analytical laboratory (Analytical lab)

Within IKA, non-nuclear radioactive waste such as radioactive sources and other radioactive material from, e.g., hospitals, are intermediate stored awaiting final disposal.

Cyclife also have an Analytical lab, where samples are analysed for radioactivity. The samples originated both from the treatment processes of Cyclife, from the other licence holder on the STP and external customers. Analyses are also done according to the Swedish Radiation Safety Authority's regulations on the protection of human health and the environment in the event of releases of radioactive substances from certain nuclear facilities (SSMFS 2008:23) e.g., environmental sampling in order to comply with the regulation.

2.1.5. Interim storage

Within Cyclife's properties at STP there is an interim storage for nuclear waste, nuclear material and non-nuclear radioactive material waiting for return to customers or waiting for treatment within the Cyclife's facilities, see Figure 16. Generally, solid secondary waste from the treatment within the facilities belongs to the customer and is returned to the customer. However, minor amounts of operational waste not possible to designate to a specific customer are considered being Cyclife's secondary waste and are handled as such.

[8] Secondary waste = Waste as a result of treatment, to final repository.

Figure 16. Striped areas: approximate locations of Interim Storage within Cyclife Sweden Ab's territory [9].

The interim storage areas together cover approximately 27 000 m^2 [9] and can, for example simultaneously store around six steam generators, 1 000 containers, 1 500 Berglöf boxes and 6 000 batches of ingots. However, there is no storage limits, radioactivity or volumes, regulated in the permits for Cyclife but it is rather limited by the logistical conditions. Most of the stored material are metallic and hence not combustible. In addition, secondary waste from the treatment is also stored, such as ashes, slag and dust, which are not combustible as they have already been through the processes.

The incoming and outgoing waste are dominated by gamma emitting nuclides such as Co-60 and Cs-137. However, the total activity on the storage areas also includes beta and alpha emitting nuclides, which do not contribute to external dose rates.

2.2. Liquid waste treatment

Liquid waste from the controlled areas is mainly from decontamination of materials for clearance, scrubber liquids from Pyrolysis and from laundry of protective clothing from radiological facilities at STP. The radioactivity in liquid waste is generally bound to particles. The liquid waste is collected in tanks before it is transferred in pipes in an underground culvert for treatment in a facility for Category 4-liquid[9] (kat.4), operated by SNAB.

The kat.4-liquid waste is treated by a precipitation process, in which the solids are allowed to sediment on the pool floor before the remaining clear liquid is released to the recipient Bergösundet south in the Tvären bay. The sediment from the process is solidified with cement in drums after evaporation for volume reduction. The treatment procedure is described in SNAB's' Safety Analysis Report and SNAB's internal instructions.

For the SMA Annex, an investigation regarding best available technology for treatment of wastewater, which focuses on evaporating techniques instead of the current culvert system, is ongoing. The evaporating technique is generally accepted within other license holders which is why it will also be evaluated within Cyclife. If the technique will be applied, all releases to water (Tvären Bay) will be analysed before release. The remaining sludge is planned to be handled within the incineration process at HA/DK.

Cyclife's current production gives a contribution of liquid waste of approximately 1 100 m^3 per year from the controlled areas [9]. An expansion of the operations to 10 000 tonnes will give an estimated maximum total amount of 1 200 m^3 per year of liquid waste.

Sanitary sewer and other wastewater from a non-radiologically classified area is transferred to SNAB's wastewater (kat.6) treatment facility for the STP. Surface runoffs are led to the STP system for the runoff.

[9] Kat.4= Liquid waste from the processes and operations from controlled areas. The acceptance criteria are a maximum content of 400 MBq/m^3 and for total alpha less than 50 kBq/m^3 (0.05Bq/ml).

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

3.1. Authorisation procedure in force

A nuclear facility requires both licenses under the Swedish Act on Nuclear Activities (1984:3) and the Environmental Code (1998:808). Also, the licensee is required to have permission for operations with ionizing radiation under the Radiation Protection Act (2018:396). These, together with the Radiation Protection Ordinance 2018:506, and the Ordinance on Nuclear Activities (1984:14) stipulate the boundaries for all nuclear activities in Sweden.

Swedish Radiation Safety Authority (SSM) has a regulatory mandate from the Swedish Government regarding nuclear safety and radiation protection and works proactively to protect the public from undesirable effects of radiation. SSM reports to the Ministry of Climate and Enterprise. The Ordinance 2008:452 includes instruction for SSM.

SSM has developed regulations (SSMFS) to give a more detailed framework for nuclear facilities. The most important regulations to this aim are shown in Table 4.

Table 4. Main SSM regulation concerning nuclear installations.

Regulation	Topic
SSMFS 2008:1	The SSM's Regulations and General Advice concerning Safety in Nuclear Facilities
SSMFS 2008:23	The SSM'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 SSM´s regulations concerning basic provisions for practices involving ionizing radiation subject to mandatory licensing
SSMFS 2018:3	The SSM's regulations concerning classification and clearance of materials, building structures and areas
SSMFS 2021:7	The SSM's regulations on the disposal of nuclear waste

SSMFS 2008:1 requires the licensee to produce a safety analysis report (SAR). The SAR must be approved by SSM in order to start building and start the operations within a nuclear facility. SSMFS 2008:1 also includes provisions on technical, organizational, and administrative measures required to maintain the safety of the facilities. The current operations within Cyclife are described in a SAR [9].

Requirements regarding limitation of releases to the environment and radiation protection is regulated in SSMFS 2008:23. According to

SSMFS 2008:23, the annual dose to the public from all nuclear facilities situated in the same area should not exceed 0.1 mSv[10]. Cyclife do not have any individual limitation of radiological releases in the permits for each facility. The fundamental requirements for operations with ionizing radiation are presented in SSMFS 2018:1. In SSMFS 2018:3 requirements with respect to clearance and associated criteria are presented.

Cyclife was formed in 2016 and has been a nuclear licensee since then. Regulatory radiation safety licenses that are valid for Cyclife are listed in Table 5.

Table 5. Valid permits and licenses regarding nuclear activities for Cyclife Sweden AB.

ID	Issued date to Vaild date	Description
M2016/01644/Ke	1st July 2016 No time limit	Operational license according to the Nuclear Act (1984:3)
SSM2015-4116	1st July 2016 No time limit	Dispensation from requirements of nuclide specific measurement of emissions
M2016/01643/Ke	1st July 2016 to 31st Dec 2024	License for interim storage and final deposit of foreign nuclear waste according to the Nuclear Act (1984:3)
SSM2022-2226-3	20th January 2023 to 31th January 2028	License for operation with ionizing radiation
SSM2019-3367-2	1st July 2019 to 30th June 2024	License for clearance of ingots from the metal treatment process
SSM2019-10715-7	21st September 2020 No time limit	Dispensation from the requirement that nuclear material and nuclear waste must be stored in a protected area
SSM2023-6768-11	28th November 2023 to 27th November 2026	Import license for nuclear waste
SSM2023-8973-3	24th February 2024 to 23rd February 2027	Export license for nuclear waste

The operator of a nuclear facility must also apply for a permit in accordance with the Swedish Environmental Code (1998:808). The Environmental Code describes the different stages of the Environmental assessment procedure. An early step in the Environmental assessment procedure is a public hearing with authorities, neighbours, and other stakeholders.

Together with the application for permit, an environmental impact assessment (EIA) must be submitted. The EIA includes a description of the activities and technologies that will be used, considering best available techniques (BAT). The EIA also needs to address the activities that are planned and the activities direct and indirect impacts on the environment and people, including but not limited to impacts on animals, land, water, air, landscape, cultural environment, resources, energy, etc.

[10] A total dose exposure from both air and water

The permit in accordance with the Swedish Environmental Code (1998:808) is issued by the Land and Environment Court. The following stakeholders are consulted in the permit procedure, SSM, The Swedish Environmental Protection Agency, the County Administrative Board, the local Environmental and Public Health Committee and are given the opportunity to propose conditions for the permit.

Cyclife plans to apply to the Land and Environmental Court at Nacka District Court for a new permit under Chapter 9 of the Environmental Code for expanded operations on the property Hånö Säteri 1:43 in Nyköping municipality, County Södermanland, Sweden. Cyclife intends to apply for a licence to process a maximum of 10 600 tonnes of radioactive waste per year, of which 10 000 tonnes at the SMA including the SMA Annex and 600 tonnes at the HA and Pyrolysis.

Cyclife currently has a permit for a maximum of 5 600 tonnes of radioactive waste per year and the valid Environmental permits for the Cyclife operations at STP are given in Table 6 below.

Table 6. Valid environmental permits for Cyclife Sweden AB.

ID	Issued date to valid date	Description
2421-6551/88	3rd Feb 1989 No time limit.	Environmental permit for incineration
5-846/89	29th June 1989 No time limit.	Completion of environmental permit with added conditions
M598-09	3rd Feb 2010 No time limit.	Environmental permit for pyrolysis
M7466-13	27th Jan 2015 No time limit.	Environmental permit for melting facility

3.2. Technical aspects

Radiological discharges from operations at Cyclife's facilities provide very small radiation doses to the most exposed family [9], see Table 10 under section 3.4.2. Emissions to the environment occur to the air and as liquid to SNAB's facilities.

The origin of the radioactive substances comes from the waste handled within the facilities and the nuclide content varies with the nuclide composition of the treated waste. Dominating nuclide contents in the off-gas monitoring measurements are shown in Table 7. In addition, Mn-54, Co-58, Zn-65, Ag-108m, Ag-110m, Sb-125, Cs-134 and Am-241 has also been detected in the off-gas monitoring.

Monitored emissions points are the ventilation systems of the facilities and the flue gas purification from the incineration and pyrolysis [9].

Table 7. Dominant nuclides in the emissions to air and the emissions during normal operation from the facilities within Cyclife operations [9].

Facility	Dominant nuclides	Emission during normal operation[11]
SMA	Co-60, Cs-137	4 MBq/year
HA	H-3, C-14	0.1 TBq/year
DK	Co-60, Cs-137	2 kBq/year
IKA	Total alfa, I-131	0.2 MBq/year

For HA, Cyclife has put in place emission limits to air for the nuclides C-14 (should not exceed 108 GBq/year) and H-3 (should not exceed 1 200 GBq/year) [9].

For the additional metal treatment facility, SMA Annex, the total emissions are very conservatively estimated to 260 MBq/year [1] and dominant nuclides are expected to be Co-60 and Cs-137. In order to estimate the emissions from the SMA Annex the emissions from the year 2013 was chosen as it was a year with a production in SMA in line with the planned production in SMA Annex. In order to make a conservative estimation a factor 10 of the emissions of 2013 has been used in the calculations.

3.3. Monitoring of discharges

Cyclife has a responsibility to monitor emissions from the facilities for radioactive content. For determination of radioactive content sampling is carried out by pumping a partial flow of the exhaust air through a particle filter. The filter is then analysed for radioactivity content, according to requirements in SSMFS 2008:23. The analyses take place at the Analytical lab. All results are documented and reported annually to SSM.

SSM may conduct control measurements to check the validity of the results.

Analyses and frequency of analyses may vary depending on production rate and nuclide content in the waste handled. The minimum frequency for gamma and total alpha analysis is once per month and for Sr-90 every 6 months. The minimum frequency for H-3 analysis in flue gases from HA is once per month. C-14 is analysed if necessary [9] e.g., in special events or if the waste treated is expected to have a significant content of C-14. Alpha spectrometric measurement is performed if total alpha indicates an emission of more than 100 kBq/week [23].

In the ventilation systems of the facilities there is a fixed sampling system (monitoring) for collecting particles for analysis. HA and IKA monitoring consists of a carbon cartridge used for sampling. The carbon cartridge is also equipped with a particle filter; see Figure 17 that shows the sketch of the carbon cartridge [24]. The sampling is continuous, and the filters are normally replaced weekly, or monthly [25].

[11] Average emission values in normal operation based on measured values in the period 2010-2019

For flue gases from HA and Pyrolysis a partial flow is withdrawn for radiological sampling, see Figure 18 below.

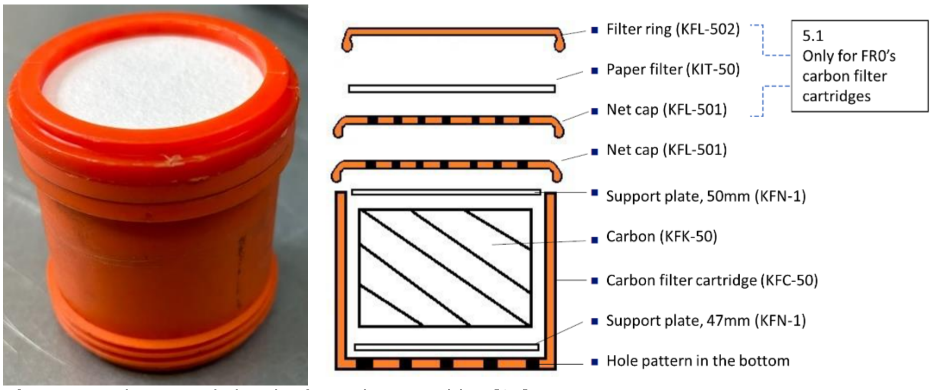

Figure 17. Picture and sketch of a carbon cartridge [24].

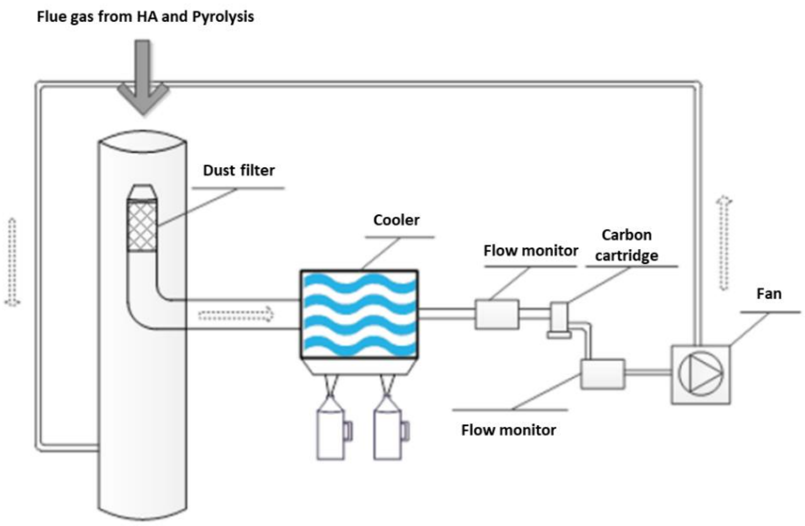

Figure 18. System for the radiological monitoring on flue gases from HA and Pyrolysis [22].

Within SMA a particle filter is used to collect particles in the aerosols of the exhaust air, Figure 19.

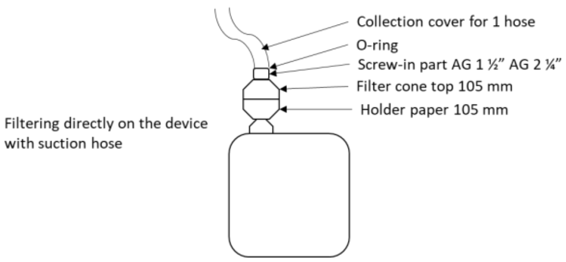

Figure 19. Sketch of monitoring system with paper filter.

The ventilation systems are equipped with alarms. The absolute filters are equipped with differential pressure measurement with an alarm for different maximum and minimum values, e.g., for the Cutting Hall within SMA the maximum and minimum values are 60 mbar (millibar) and 15 mbar respectively [26].

Unmonitored emission points occur from some parts of the facilities, e.g., ventilation of premises and fume hoods in Development Hall at SMA and from the general ventilation system of the building R0-A which houses the IKA operations. However, the consequences of these emissions have been risk assessed to be very small according to the facilities' Safety analysis. The ventilation and fume hoods for the Development Hall at SMA are equipped with an absolute filter.

There is always a risk of diffuse emissions from, e.g., doors associated to door openings. The ventilation maintains an under-pressure in the facilities, which reduces the risk of diffuse emissions during door opening. The risk is minimized by instructions and is regulated in Safety technical operating conditions (STF). The consequences of diffuse emissions are very small according to the facilities' Safety analysis.

To verify that the alarm system and monitoring systems are working, rounds take place in the facilities in accordance with STF. When a failure occurs, there are instructions and routines for measures to maintain the facility in so-called safe operation, which is regulated in the facilities' STF.

3.4. Evaluation of transfer to man

3.4.1. Model description

For calculation of the releases in the vicinity of the facilities the PREDO model is used [12], which is a model developed jointly for all nuclear facilities in Sweden by the company Vattenfall. The PREDO model is described in detail in a number of reports, e.g. [12] and [27].

PREDO covers the air dispersion modelling, the terrestrial dose modelling and the aquatic dispersion and dose modelling for discharges to the sea. Parameters within the PREDO model have been adjusted to local living habits [12]. This section describes the air dispersion modelling and the terrestrial dose modelling. The aquatic model is described in section 4.4.1.

Meteorological data used for the dispersion calculations for STP, i.e. wind direction, wind speed, temperature (surface and vertical difference) are local mast measurements combined with MESAN data (where measurements are missing) [12]. MESAN is a tool that predicts meteorological conditions using interpolations between surrounding measurement stations and calculations, for further details see Ref. [12] and references therein. The wind rose in Figure 8 in section 1.3 in this document shows the wind measured by the local mast. The dispersion calculations used in the models are performed hour by hour, through the period 2008-2012.

The methodology for atmospheric dispersion is based on an analytical Gaussian model developed by the Swedish Meteorological and Hydrological Institute (SMHI) [27]. The output of the modelling consists of air concentrations at the height 1.5 m above the ground, wet deposition, and dry deposition. Results are calculated over the area 20 km * 20 km with a 100 m

* 100 m resolution. Five different nuclide groups are considered: H-3, C-14, Co-60, I-131 and noble gases.

There are three air discharge paths set up in the PREDO models for STP, however the emission pathway R2/SVAFO is not presented in this document since it has been decommissioned. In Table 8 the technical data for the other two discharge paths are presented: the incineration HA and a fictitious source. The fictitious source is the assumed pathway of all other releases from STP. These releases mainly take place via lower stacks at the top of buildings, and the air dispersion from these stacks are assumed to behave similarly.

Table 8. Technical data for air discharge paths at STP [12].

	HA	Fictive
Hight Chimney, from ground level [m]	50	20
Inner diameter [m]	0.79	0.43
Air flow through chimney [m^3/h]	5 000	10 115
Temperature Air flow [°C]	150	20

The resulting air concentration from a release of 1 Bq/s of Co-60 from the facility HA is shown in Figure 20, and the resulting deposition is shown in Figure 21. The air concentration profile is valid for all radionuclides since no ingrowth, decay or plume depletion is considered. The different deposition types (wet and dry) depend on the nuclide group.

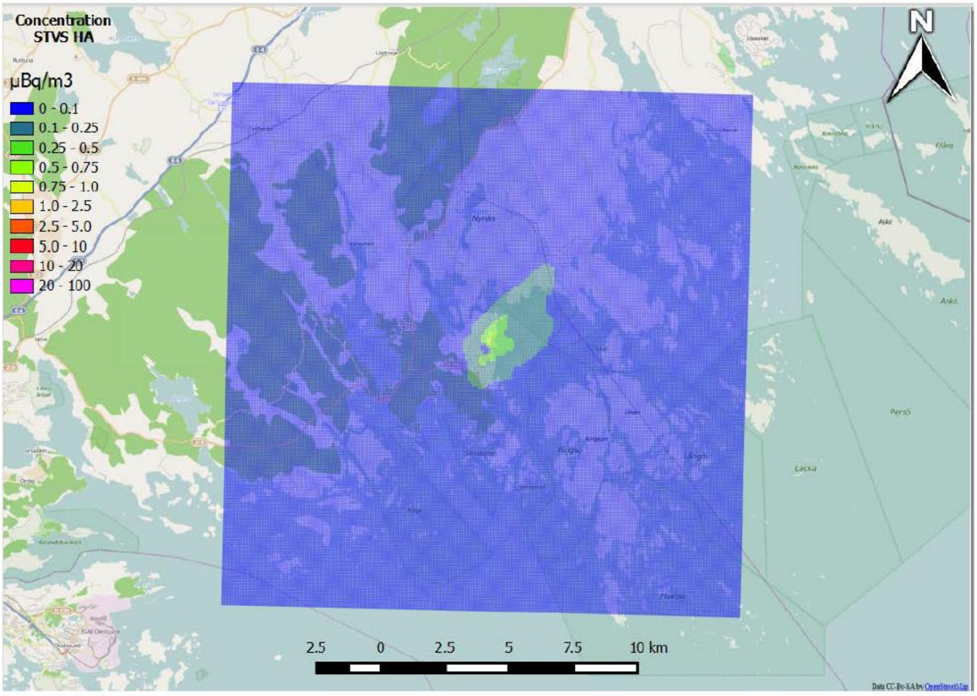

Figure 20. Concentration in air from source HA (resolution of 100 x 100 m) [12].

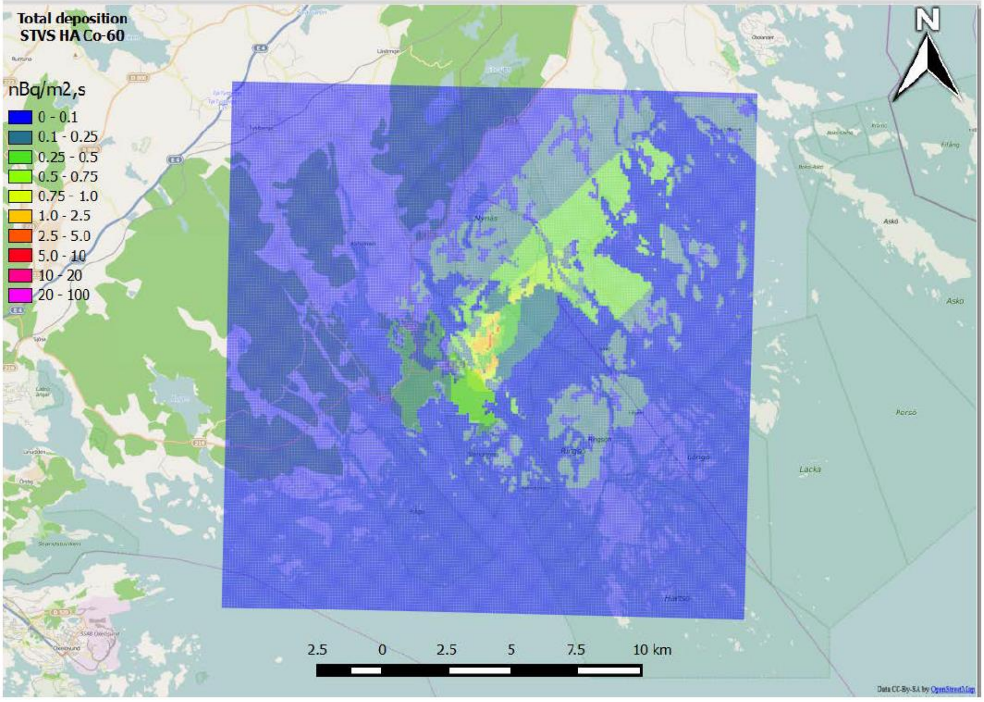

Figure 21. Total deposition of Co-60 (nBq/m^2,s) and source HA for emission [12].

Radionuclide transport in terrestrial systems are described in a compartment model, where transport is governed by differential equations. The concentration in each compartment is assumed to be constant, and if the need for a finer granularity is identified, the compartments can be made smaller. The terrestrial transport modelling includes dispersion, irrigation, water runoff, bioturbation, sea spray and flooding.

Land use in the area has been classified and a number of objects (lakes, croplands, pastures, forests, gardens) that may contribute to exposure to humans have been identified. These objects are called receptors. Each receptor consists of various compartments, which are assumed to have homogeneous properties.

The two or three receptors of each type (forest, pasture, cropland, garden, lake) which have the highest calculated concentrations of radionuclides have been selected and further characterized with object-specific data, such as soil type in croplands, biomass production in forests and runoff from the lakes. Chapter 1 in this document gives and overview of the surroundings around STP and the respective land use, and the detailed parameters that are used in PREDO are presented in Ref. [12]. Table 9 shows the different objects that were selected, their types of eco systems and their respective area.

Table 9. Data for objects in PREDO-models for STP [12].

Designation object	Ecosystem	Area [m^2]	Alternative name
G1	Garden	9.00E+00	Building 1
G2	Garden	9.00E+00	Building 2
C1	Agricultural land crop	3.01E+04	
C2	Agricultural land crop	1.19E+05	
C3	Agricultural land crop	1.22E+05	
P1	Hay and pastureland	1.11E+04	
P2	Pastureland	8.93E+04	
P3	Pastureland	1.24E+05	
F1	Forest	1.35E+06	
F2	Forest	2.13E+07	
L1	Lake	1.08E+05	Lillsjön
L2	Lake	9.09E+05	Rundbosjön

Transport in the receptors is calculated, and the doses to humans from each receptor is calculated. Humans are exposed to the risk of radionuclide exposure and resulting doses when they are residing in a receptor and eating products from it. Exposure pathways includes inhalation, external exposure, and intake of berries, game, mushrooms, water, various crops etc.

Various types of families, such as vegetarians, farmers, fishers etc., are considered, and doses to the age groups recommended in ICRP Publication 101a are calculated. The age groups are:

- 0-5 years (infant)
- 6-15 years (child), and
- 16-70 years (adult).

The doses are calculated assuming a release of 1 Bq/year during 100 years. The reason for calculating the doses after 100 years is that equilibrium has, for most radionuclides, been reached in the eco systems after this time. The resulting dose factors are used for calculating the dose given a certain release as measured by the release monitoring.

The components in the PREDO model, at the top level, are visualized in Figure 22.

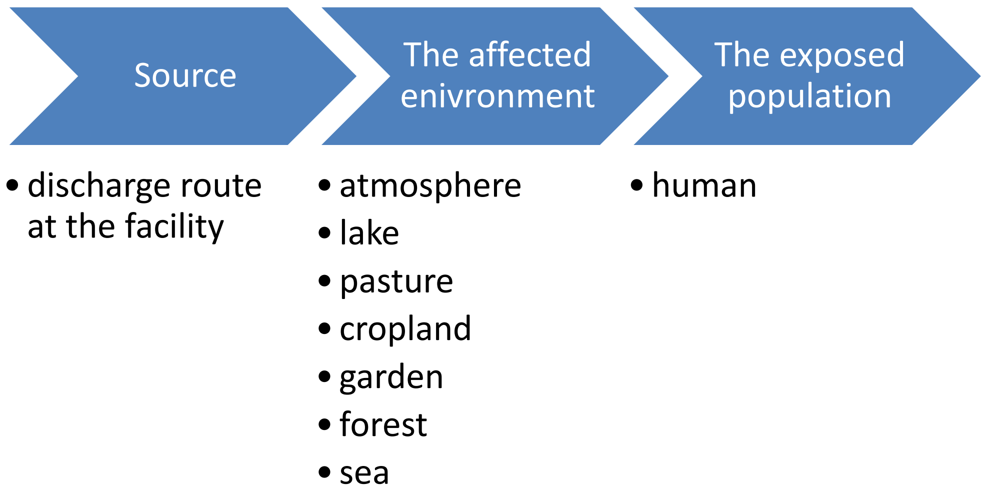

Figure 22. Top level components within PREDO model for STP.

3.4.2. Evaluation of the concentration and exposure levels

The maximum exposure for adults, children, and infants in the vicinity of the facilities from emissions released under normal conditions are estimated to be far below 10 µSv per year at a production of 10 600 tonnes, see Table 10. Therefore, doses to other Member States are left uncomment in this document.

Table 10 is based on the highest actual emission values for each of the facilities SMA, HA/DK and IKA for the years 2019 to 2022, correlated and scaled up, to represent the full license production of 5 600 tonnes. For the SMA Annex a calculated value is based on actual releases for SMA with a scale factor of 10. The factor 10 is to account for a higher incoming activity to SMA Annex and to consider uncertainties and differences in customers' waste. Supporting documents are the Emissions reports for STP, reported to SSM for the years 2019 – 2022. The time period (2019-2022) is chosen as emission calculations are available based on PREDO during this period, previously another model was used for these calculations.

The highest calculated dose from emissions from SMA during the period 2019 – 2022 was 1.1E-06 mSv (year 2022) and 1 662 tonnes was melted. This means the value for SMA in Table 10 is scaled up with a factor 3 to correspond to 5 000 tonnes. As mentioned above, the value for SMA is then scaled with factor 10 to account for a higher incoming activity and additional 5 000 tonnes for melting for SMA Annex.

For HA a scale factor 2 is used, due to the production level was 312 tonnes incinerated when highest value, 2.8E-06 mSv (year 2019) occurred.

Exceptional pathways or other ways of exposure to a Member State are not expected during normal operations and is therefore left uncomment.

Table 10. Calculated maximum exposure levels to most exposed family in the vicinity to the facilities during a maximum level of production (10 600 tonnes) during normal operations.

	mSv/year		
	0-5 year	**6-15 year**	**16-70 year**
SMA	8.7E-06	1.5E-05	3.3E-05
HA/DK	1.7E-06	2.4E-06	5.6E06
IKA	1.8-07	6.1E-08	3.5E-08
SMA Annex (estimated)	8.7E-05	1.5E-04	3.3E-04
Total	9.8E-05	1.7E-04	3.7E-04

3.5. Radioactive discharges to atmosphere from other installations

Effective dose to the critical group from all facilities located within the same geographically defined area, thus applies to all license holder within STP, shall not exceed 0.1 mSv/year. If the dose is expected to exceed 0.01 mSv/year, realistic calculations of radiation doses shall be carried out [2].

Table 11 shows the calculated doses from emission to the environment from all nuclear facilities at STP during current conditions excluding the planned expansion of production. Annual reports to SSM show that the radiation dose to the public is by a large margin less than the requirement in SSMFS 2008:23. Doses to representative person due to airborne emissions from STP, including a production of 10 000 tonnes within Cyclife, are estimated to be less than 0.001 mSv/year.

Table 11. Calculated dose, to the most exposed representative person, from emissions to the environment from all nuclear facilities at Studsvik Tech Park during the year 2016-2021 [28].

	2016	**2017**	**2018**	**2019**	**2020**	**2021**
Calculated highest dose to the most exposed representative person (mSv)	4.3E-05	4.4E-05	1.2E-05	5.0E-05	1.1E-05	0.8E-05
- of which the calculated dose from emissions to air (mSv)	0.7E-05	0.2E-05	0.5E-05	4.2E-05	0.1E-05	0.2E-05

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

4.1. Authorisation procedure in force

See section 3.1 for description of legislation and authorisation procedures.

4.2. Technical aspects

Section 2.2 describes the liquid waste that arises within Cyclifes' operations. However, the waste is mainly from decontamination of materials for clearance, scrubber liquids from Pyrolysis and from laundry of protective clothing from radiological facilities at STP. The origin of the radioactive substances comes from the waste handled within the facilities and the nuclide content varies with the nuclide composition of the treated waste.

Dominating nuclide from SMA in the wastewater is normally Co-60 but other nuclides can be detected, such as H-3, Fe-55, Ni-63, Sr-90, Cs-137, U-238, Pu-241 and Am-241 [29]. This is also estimated to apply for SMA Annex.

Table 12 shows the estimated annual amount of wastewater to kat.4 generated, dominant nuclides and the emissions during normal operation. For HA/DK the dominant nuclides are Co-60 and Cs-137. Other nuclides from HA/DK to a significant extent is Ag-110, Mn-54, Zn-65, Fe-55, H-3, C-14, Ni-63 and Fe-55 [29].

Note that HA/DK and Pyrolysis has the same emission route to the kat.4. The same goes for IKA and Analytical lab that also has a combined emission route to the kat.4-system.

Table 12. Dominant nuclides, amount generated and emission for the wastewater to kat.4 during normal operation from the facilities within Cyclife operations

Facility	Estimated annual amount generated	Dominant nuclides	Emission during normal operation
SMA	approx. 40 m^3	Co-60, Cs-137	4 MBq/year
SMA Annex	approx. 40 m^3	Co-60, Cs-137	4 MBq/year[12]
HA/DK incl. pyrolysis	approx. 400 m^3	Co-60, Cs-137	120 MBq/year
IKA and Analytical lab	approx. 600 m^3	Total alfa, I-131	0.2 MBq/year

Cyclifes' contribution of emissions to the recipient from liquid waste are added and reported together with the other establishments at STP. However, Cyclife is required to follow acceptance criteria, for the SNAB facility for liquid waste treatment. This is regulated through different agreements, and a

[12] Estimated value may be adjusted after the ongoing BAT analysis for handling the liquid-borne waste in the SMA Annex is completed.

control of the liquid is done before release to SNAB. The control is done by analysing water samples at Analytical lab. The result needs to be less than 400 MBq/m^3 (400 Bq/ml) for a total activity content and for total alpha less than 50 kBq/m^3 (0.05 Bq/ml) [30].

4.3. Monitoring of discharges

To verify that the liquid waste systems are working, rounds take place in the Cyclife facilities according to STF. When a failure occurs, there are instructions and routines for measures to maintain the facility in so-called safe operation, which is regulated in the facilities' STF.

The treated liquid waste at SNAB facility is analysed at Analytical lab before release to the recipient. Analytical lab analyses the samples from the liquid waste for gamma emitting nuclides, total alpha content, H-3, Sr-90 and actinides [31].

For kat. 4 the actinides analysed are: americium, curium, plutonium, and uranium which are chemically separated and electrodeposited before being analysed with alpha spectrometry.

4.4. Evaluation of transfer to man

4.4.1. Model description

As mentioned in Section 3.4.1 the modelling tool PREDO is used also for the modelling of aquatic transfer of radionuclides and doses to man. An overview of the model is presented in Ref. [8].

Hydrological data from SMHI and calculations using the software THREE-TOX (see Ref. [8] and references therein) is used for modelling of water exchange between adjacent water volumes. This data is used as input in a customised version of the POSEIDON software (see Ref. [8] and references therein).

POSEIDON is a compartment model which models transport of radionuclides in water, sediments, and marine organisms. The full Baltic Sea model in POSEIDON consists of 81 boxes, see Figure 23, each of which consist of a number of vertical water layers and three sediment layers. The model has been validated against experimental data on Cs-137 from releases from nuclear weapon testing, nuclear facilities and the Chernobyl accident.

For calculation of releases from STP, a reduced system with fewer and smaller boxes is used; see Figure 24. Cyclife's emissions to the recipient go through the common system for the liquid releases at STP, which take place in the "coastal box" which covers the bay Tvären. Table 13 describes the parameters used for the reduced box system used in in PREDO for calculations of releases from STP.

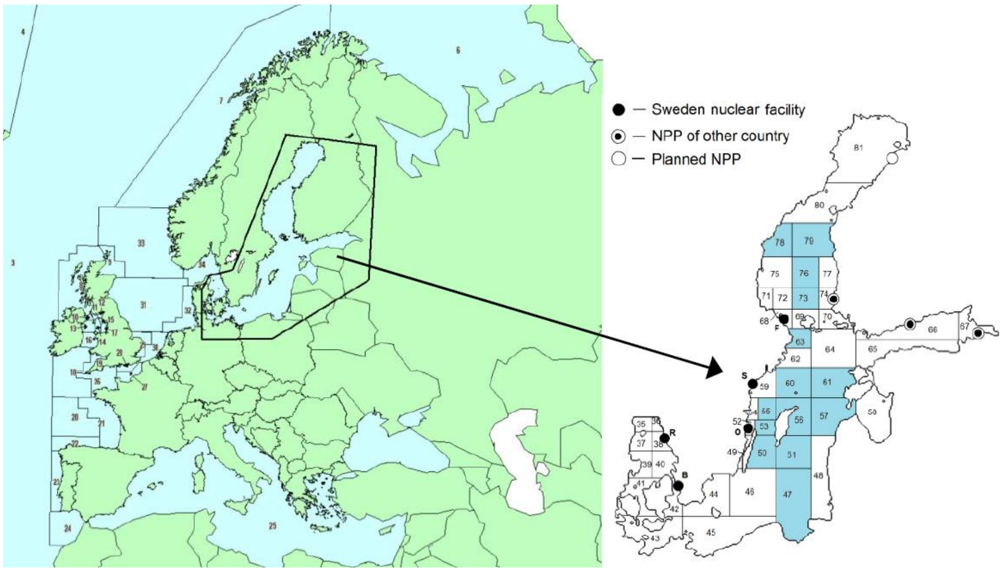

Figure 23. POSEIDON box model of the Baltic Sea [8].

Figure 24. Reduced box system around the STP according to the model in [8]. (Map from Earthstar.)

Table 13. Parameters, reduced box system for STP [8]

Box and Name	Volume (km^3)	Areas (km^2)	Depth (m)	Exchange rate ($km^3 \cdot yr^{-1}$)
1 Baltic Sea	21 500	$3.9 \cdot 10^5$	55	-
2 Studsvik regional box	314	6 280	50	7 720
3 Studsvik internal box	2.0	154	13	103
4 Studsvik coastal box	0.216	18	12	7.3

Radioactive nuclides are transported, both vertically and horizontally, between the different water compartments by currents and turbulent dispersion. Modelling of radionuclide transport to and from each of the three sediment layers considers sedimentation, diffusion, resuspension and bioturbation. For the transfer of radionuclides to marine organisms, the organisms' level in the food chain and the distribution of the nuclides inside the organism are considered. For example, caesium accumulates in muscle parts of the organism and is thus transferred further in the food chain when it is consumed by a predator. Strontium on the other hand accumulates in the skeletal parts of the organism which are considered not consumed and thus do not continue in the food chain. The varying salinity in the Baltic Sea is taken into account in the transport modelling. Transport to terrestrial objects via irrigation and sea spray is also considered.

Internal exposure pathways considered are seafood consumption, consumption of crops, meat and milk from areas affected by irrigation and flooding, water consumption and inhalation of sea spray. External exposure pathways considered are beach occupancy, swimming and boating. An overview of the radiological exposure paths is presented in Figure 25.

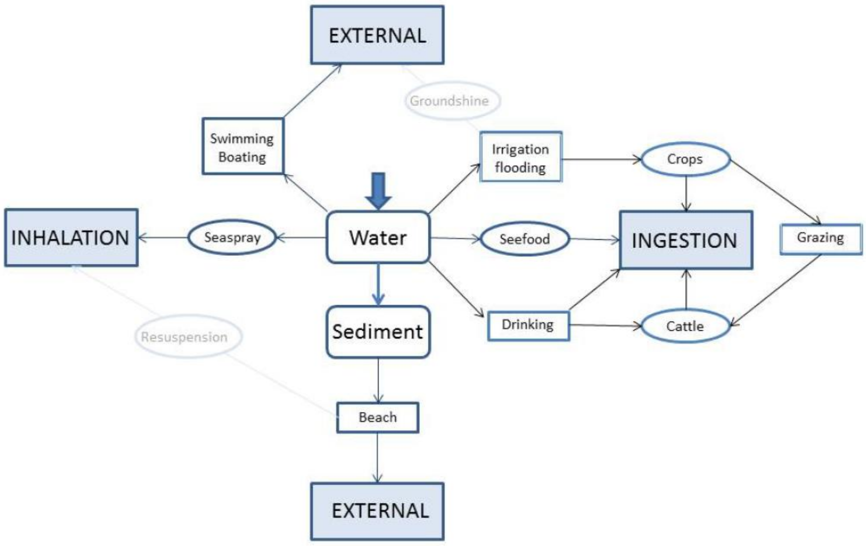

Figure 25. Overview of the relevant radiological pathways *[8]*. The two pathways that are transparent (ground-shine after irrigation/flooding and resuspension of beach material) were considered, but not taken into account in the final model.

Various types of families, such as vegetarians, farmers, fishers etc., are considered, and doses to the age groups recommended in ICRP Publication 101a are calculated. The age groups are:

- 0-5 years (infant)
- 6-15 years (child), and
- 16-70 years (adult).

4.4.2. Evaluation of concentrations and exposure levels

As with airborne emissions, the emissions from liquid release are estimated to be below 10 µSv per year in terms of the maximum exposure for adults, children, and infants in the vicinity of the emission points (Bergösundet and Tvären), see Table 14. Therefore, doses to other Member States are left uncomment in this document.

Table 14 is based on the highest actual values for kat.4[13], kat.5[14] and kat.6[15] from the STP for the years 2019 to 2022, correlated and scaled up in two steps. In step 1 the values are correlated to a maximum production within Cyclife for current permits on 5 600 tonnes and step 2 scaled up to a maximum production at 10 600 tonnes. To support this the Emissions reports for STP, reported to SSM for the years 2019 – 2022 are used. The time period (2019-2022) is chosen as emission calculations are available based on PREDO during this period, previously another model was used for these calculations.

Exceptional pathways or other ways of exposure to a Member State due to emissions to water are not expected during normal operations and is therefore left uncomment.

Table 14. Calculated maximum exposure levels to groups in the vicinity of the facilities, during a maximum level of operation.

	mSv/year					
	Average family			Most exposed family		
	0-5 year	6-15 year	16-70 year	0-5 year	6-15 year	16-70 year
Bergösundet (kat.4)	5,9E-05	4,9E-05	5,0E-05	6,6E-05	5,3E-05	5,7E-05
Tvären (kat.5)	1,8E-07	1,3E-07	1,3E-07	1,9E-07	1,4E-07	1,3E-07
Tvären (kat.6)	1,6E-06	9,6E-07	2,3E-06	4,8E-06	3,1E-06	6,6E-06
Total	6,1E-05	5,0E-05	5,2E-05	7,1E-05	5,6E-05	6,4E-05

4.5. Radioactive discharges into the same receiving waters from other installations

The trend charts in Figure 26 (for kat.4) show annually accumulated emission values in Bq for detected nuclides during the period 2012 – 2021. Please note that the scale of activity in Bq is logarithmic and that the figure only is showing the measured nuclides during operational levels respective year.

Table 15 shows the calculated dose from emissions to the environment from all nuclear facilities at STP during the year 2016 – 2021. Estimated doses to representative person due to liquid borne releases from STP, including a production rate of 10 000 tonnes within Cyclife, are to be less than 0.001 mSv/year.

[13] Kat.4= Liquid waste from the processes and operations from controlled areas. The acceptance criteria is a maximum content of 400 MBq/m^3 and for total alpha less than 50 kBq/m^3 (0.05 Bq/ml).
[14] Kat.5 = Liquid waste from the processes and operations from other controlled areas witihin STP. The acceptance criteria is < 0,7GBq total alpha, <22 TBq Tritium and <122 TB of other beta activity.
[15] Kat. 6 = Sewage for the STP.

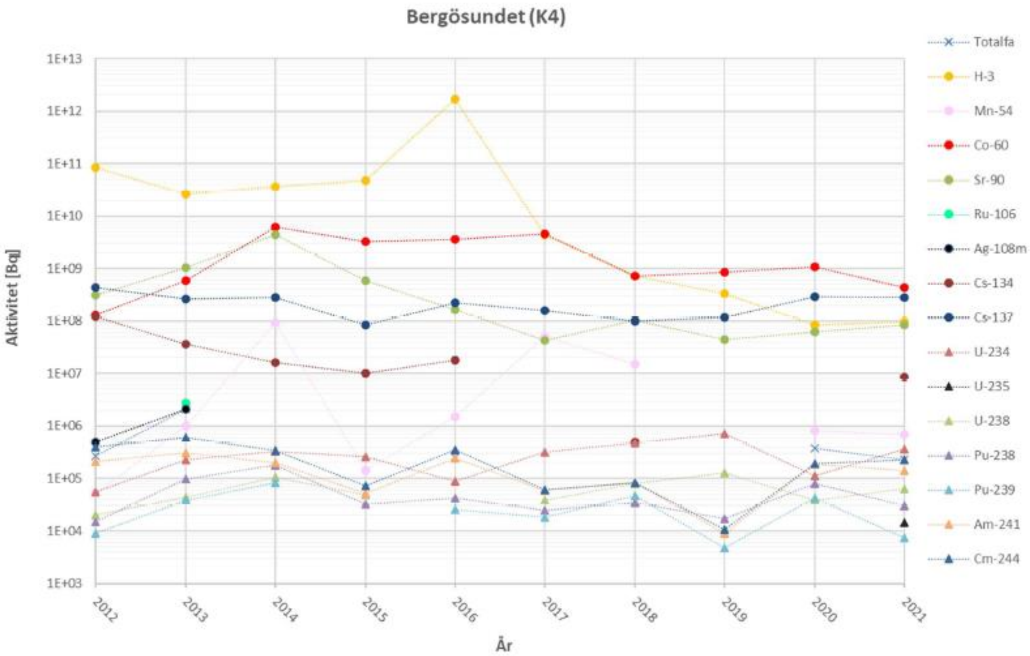

Figure 2626. Trend chart of emission from STP to Bergösundet for the period 2012-2021 [31].

Table 15. Calculated dose, to most exposed representative person, from emissions to the environment from all nuclear facilities at Studsvik Tech Park during the year 2016-2021 *[28]*.

	2016	2017	2018	2019	2020	2021
Calculated highest dose to most exposed representative person (mSv)	4.3E-5	4.4E-5	1.2E-5	5.0E-5	1.1E-5	0.8E-5
- of which the calculated dose from discharges to water (mSv)	3.6E-5	4.2E-5	0.7E-5	0.8E-5	1.0E-5	0.6E-5

5. Disposal of solid radioactive waste from the installation

5.1. Solid radioactive waste

All nuclear license holders are responsible for their nuclear waste arising during operation and decommissioning which means the waste belongs to the customers and is sent back to the customers after treatment within Cyclife processes. However, some waste generated during the operations cannot be traced to a specific customer and can therefore be disposed under Cyclife's permit for disposal of small amounts of foreign nuclear waste. In Table 16, Cyclife's secondary waste that arose in 2022 within the facilities SMA and HA/DK is summarised.

Table 16. Cyclife Sweden AB's secondary waste arisen in 2022 at Cyclife's facilities HA/DK and SMA [32].

Waste type	Weight (tonnes)	Comment
Metals	27	Raw waste
Wastes originating from melting and incineration	66	E.g., ash, furnace lining, dust, and slag
Organic material	6	Raw waste
Other material	25	E.g., concrete, lime bags and glass (Partial raw waste)
Total	**124**	

Categories of secondary solid radioactive waste that may arise within Cyclife operations are shown in Table 17. Most of the generated waste will be sent back to the customer and most of the lime from the incinerator and furnace lining from the metals treatment facilities will be subject to clearance and disposed of in a landfill.

Table 17. Categories of secondary waste that may arise within Cyclife Sweden AB's operations [9].

Categories according to SKB [33]	Examples of waste	Facility
Long-lived low- and intermediate -level waste	Combustible/non-combustible waste	HA/DK, SMA, SMA Annex, IKA
Short-lived low- and intermediate-level waste	Combustible/non-combustible, Scrap metal, Electronics, Liquid-waste	HA/DK, SMA, SMA Annex, IKA
Material released from regulatory control.	Ingot, Waste oil, Furnace lining, Electronics, Scrap metal	HA/DK, SMA, SMA Annex, IKA

5.1.1. Short-lived low- and intermediate-level waste

As far as possible and as shown in Figure 27 and Figure 28, the waste is sorted into combustible and meltable waste fractions. For waste fractions not suitable for melting or incinerations the options are either clearance after decontamination through the DFA either for reuse, recycling or for disposal as hazardous waste. Any remaining waste after this is considered radioactive waste and will be disposed of in a facility operated by SKB.

Characterisation of large components with complex geometries are difficult. If the metal is melted in an induction furnace it is homogenised, and one sample represents the melt for characterisation.

Both incineration and melting lead to a volume reduction of waste and results in fewer waste packages for disposal. Incineration also results in an inert waste form suitable for disposal. The ingots produced by melting can in many instances be subject to clearance and thereafter recycled into the non-nuclear industry.

Some waste has low activity contents so it can undergo clearance. Other wastes and components, which cannot be treated as they do not meet the acceptance criteria for treatment, are sorted, characterized, and conditioned for storage awaiting final disposal.

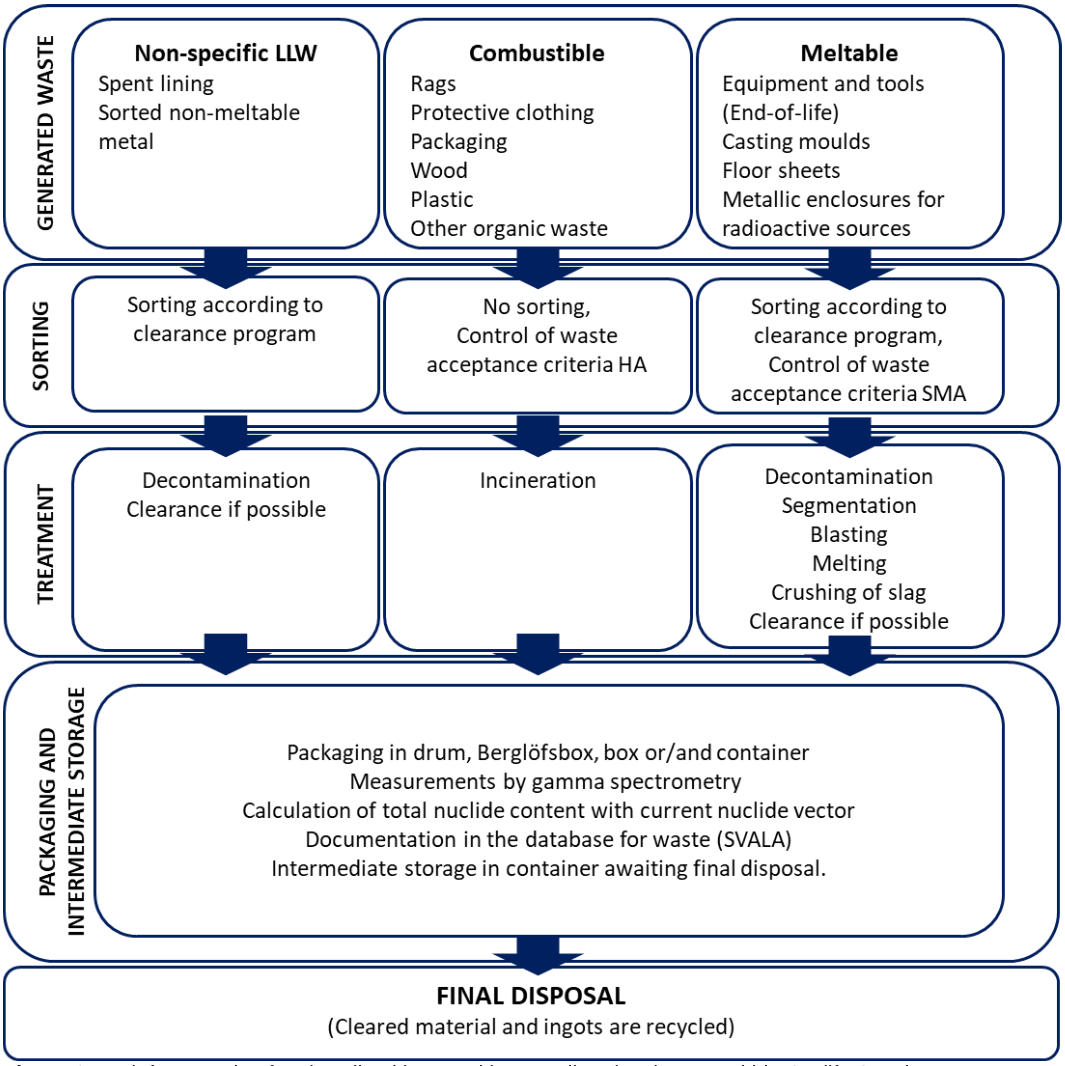

Figure 27. Brief waste plan for short-lived low- and intermediate-level waste within Cyclife Sweden AB *[9]*.

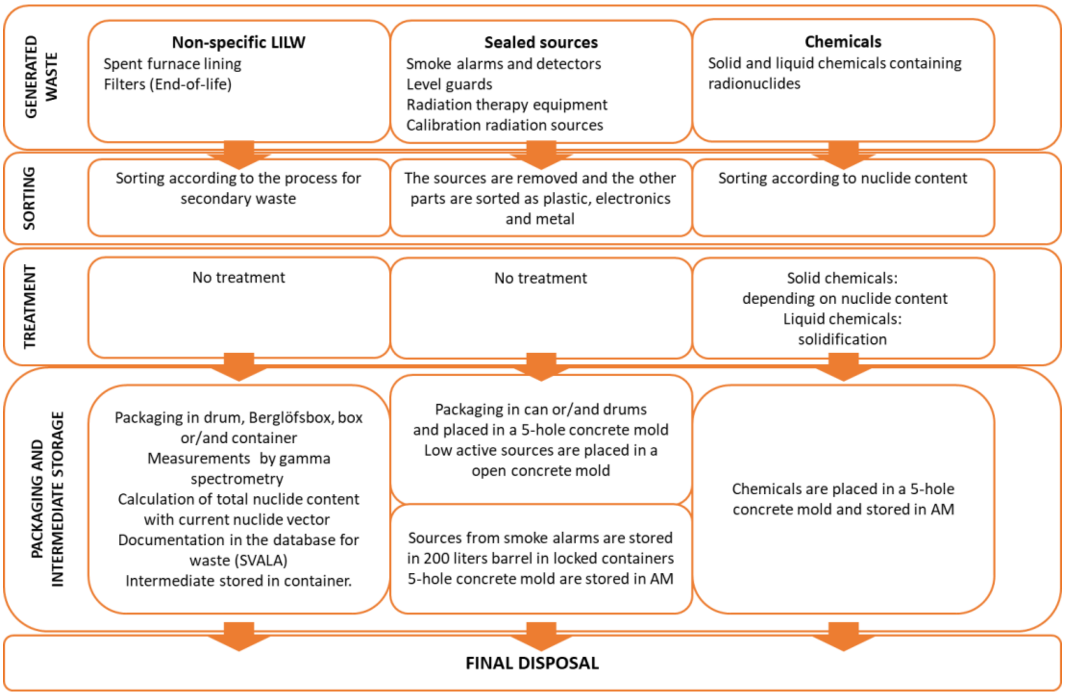

Figure 28. Brief waste plan for long-lived low- and intermediate-level waste Cyclife Sweden AB [9].

5.1.2. Storage arrangements on site

Waste, awaiting treatment within the Cyclife facilities, recycling after clearance, final disposal or to be sent back to customers is interim stored in ISO-containers. The containers are placed outside on hardened and paved surface within Cyclife's area at STP, as shown in Figure 29. Large components are also stored on hardened and paved surface awaiting treatment. Depending on the material or waste of the large component stored different weather protection can be used such as tent or tarps. Logistic conditions may affect the stored volumes and the capacity for storage.

Figure 29. Storage of materials and waste waiting for treatment, return to customer or final disposal [9].

Ingots are stored either weather protected or outside depending on, if the ingots are for decay or awaiting transport for recycling as shown in Figure 30. Waste and material with a high dose rate can be stored in a cavern (bedrock) facility called AM owned by Svafo.

Figure 3030. Storage of ingots waiting for recycling [9].

5.2. Radiological risks to the environment

During 2013 a project called PREDO was launched by Vattenfall to develop an assessment tool for the radiological consequences caused radioactive release from the Swedish nuclear facilities including from the STP. PREDO are used for making simulations for selected inputs and to extract radionuclide concentrations in soil, sediment, water and air. To determine the risk to the environment by simulation in PREDO, a simulation of a consistent annual emission of 1 Bq/year over a period of 100 years for each relevant nuclide has been used. After 100 years the majority of nuclides have achieved stability in the ecosystems and an accumulation in the environment no longer occurs [34].

Calculations of dose rates for a sample of reference organisms have been made with ERICA, a modelling program specifically developed for radiological impact assessments to the environment. The ERICA program uses a screening level of 10 μGy/h, values below this level are considered to result in minimal risks of injury with respect to reduced reproduction or increased mortality [34].

Based on the calculations [34] it has been shown that the operation of the Cyclife facilites does not impose any radiological impact on the surrounding environment and biota.

STP is surrounded by industrial fences, which among other precautions prevents unauthorized access to the waste and the facilities. The waste and materials are also stored in such a way that the spread of contamination to the environment is prevented, and different controls are carried out continuously to ensure this.

5.3. Off-site arrangements for the transfer of waste

In Sweden, SKB is responsible for the development, building and operation of final repositories for Swedish radioactive waste. This is regulated trough agreements between SKB and the license holders.

Shipments and transports of ADR class 7 in Sweden comply with the requirements stipulated in the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) and the International Maritime Dangerous Goods Code (IMDG).

5.4. Release of materials from the requirements of the basic saftey standards

Clearance of material, buildings and land used in activities involving ionizing radiation is regulated in SSMFS 2018:3 which is in line with directives from EURATOM regarding clearance criteria.

In regulation SSMFS 2018:3 clearance of materials for free use, including ingots from melting, or waste for disposal as hazardous waste are possible. The nuclide specific limits for general and conditional clearance are given in SSMFS 2018:3 appendix 2 and 3 respectively. Clearance of ingots is also possible within a permit from SSM which allows for clearance according to clearance levels given in the European commission’s recommendation RP89.

The regulation SSMFS 2018:3 also stipulates that control programs for clearance shall be submitted to SSM. Currently Cyclife has two control programs, one for clearance of ingots and one for clearance of material.

In Figure 31 below the process for clearance is given. The process in Figure 31 starts when the ingots or materials are ready for clearance i.e., all earlier process steps are completed.

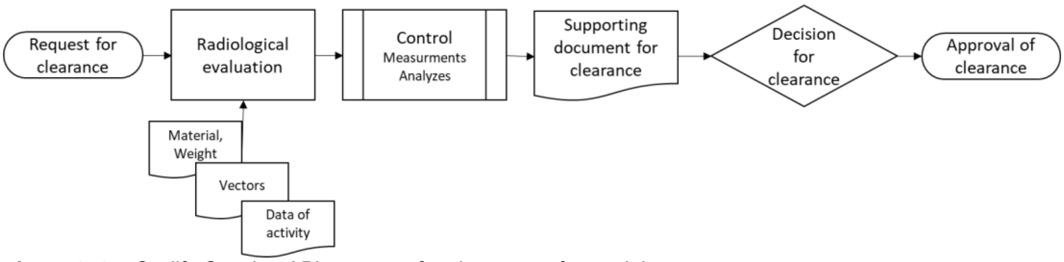

Figure 3131. Cyclife Sweden AB's process for clearance of materials.

The radiological evaluation for clearance includes gamma measurement data on samples or measurements on the item subject to clearance, application of a nuclide vector to include hard to measure nuclides as well as knowledge of material and weight of the item.

Controls includes surface contamination measurements. The supporting documentation is a clearance report the undergoes quality checks before being subject to the decision of clearance. The final approval finalises the clearance process.

Dilution of radioactive material to enable clearance is strictly forbidden in SSMFS 2018:3.

Within Cyclife's operations, different types of materials arise that are possible for clearance e.g. equipment, packaging, fluorescent lamps, batteries, chemicals, ingots, containers etc. All material which has undergone clearance is reported annually to SSM. The mass from each of Cyclife's facility during 2021 is presented in Table 18.

Table 18. Cleared material within Cyclife Sweden AB year 2021 [35].

Facility	Amount (tonnes)
IKA	3.2
Outsorted container-project	37[16]
HA	1.6
SMA	13
Ingots	1 500[17]

[16] Total activity is applied to only 1 000 kg
[17] Here of RP89 approx. 200 000 kg

6. Unplanned releases of radioactive effluents

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

The licensee is responsible to identify and analyse relevant accidents and SSM regulation SSMFS 2008:1 stipulates “The safety analyses shall be based on a systematic inventory of events, event sequences and conditions which can lead to a radiological accident”.

Cyclife’s SAR [9] for the facility includes an analysis of the capacity of barriers and systems for defence-in-depth to prevent radiological accidents and mitigate consequences. The analysis is based on a systematic review of events, sequences and circumstances that can lead to a radiological accident.

External events that have been risk assessed that could mean a risk of unplanned radioactive release are flooding, forest fires, extreme rain or snowfall, extreme temperatures, strong winds, solar storms, lightning strikes, seismological events, airplane and helicopter crashes, and breakdowns in nearby companies’ facilities.

Internal events that have been risk assessed that could mean a risk of unplanned radioactive release are different operational deviations that could lead to fire within the facilities, and media loss and leakages that would mean a risk of emissions from the facilities such as power outages and interruptions in ventilation.

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

The authority SSM decides which classification based on threat category a facility should have, which is regulated in SSMFS 2014:2. The classification is based on the consequences of an accident and the need for protective measures that may arise. SSM has therefore looked at various scenarios that could contribute to a spread of activity [36], these scenarios are:

- Activity release in case of fire SMA
- Activity dispersion due to explosion during blasting (SMA)
- Filter fire in the incineration facility
- Fire or explosion due to gas leakage in the pyrolysis hall
- Filter fire in the pyrolysis facility
- Explosion in the pyrolysis chamber
- Explosion or fire during the cleaning of pyrolysis chamber
- Fire in stored waste

- Overall facility fire

SSM have made a detailed calculations for scenario of a large fire in HA/DK including the Pyrolysis. The scenario is that all radioactive content within the facility and the filters are released during the fire. The calculations show that the event would give very low doses to the public, 0.026 mSv to adults at a distance of 300 m and under seven days from the event starts [36].

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

6.3.1. Accidents entailing releases to atmosphere

Emissions in the event of disruption of operations are based on the estimated source term for each installation. The event that is considered to have an impact, of importance, on the surroundings is fire in the facilities or at the interim storage outside [37], [38], [39], [40], [41], [42].

The methodology for the environmental impact calculations follows the Swedish power plants and SSM jointly developed methodology manual "Methodology Handbook for Realistic Analysis of Radiological Consequences". Standardized dose calculations are made according to Chapter 5 of the methodology manual [43].

From 0 - 200 meters from the source of emissions, dose conversion factors with an emission height of 10 meters are used and for above 200 meters from the emission source, an emission height of 20 meters is used. The release of activity to the surroundings is calculated according to Equation 1, where:

A_n = Realesed activity of nuclide "n" when fire (Bq)
I = Total inventory of activity within the facility/area (Bq)
Nuc_vec_n = proportion of total inventory of activity which is the nuclide "*n*" (-)
FRF_n = emancipation fraction of nuclide "*n*" when fire (-)

$$A_n = I \cdot NUC\_vec_n \cdot FRF_n$$

Equation 1. Equation for determining the release of activity *[37]*, *[38]*, *[39]*, *[40]*, *[41]*, *[42]*.

The dose is calculated by multiplying the inventory of activity for each nuclide with a dose factor (mSv/Bq) which is nuclide specific. The dose factor for each nuclide is determined by the height of releases, the distance to the release sources, and by the meteorology parameters that are stated in [43].

When released to the environment, distribution occurs in the atmosphere. The distribution is modelled by applying a Gaussian plume to a straight line at the level of the emission source. The effective dose to adults is calculated as shown in Equation 2, where:

D_{adult} = Effective dose to adults (mSv)
A_n = Realesed activity of nuclide "n" when fire (Bq)
$D_{f,cl,n}$ = Nuclide specific dose conversion factor for external dose from activity in air (mSv/Bq)
$D_{f,gr,n}$ = Nuclide specific dose conversion factor for external dose from activity on ground (mSv/Bq)
$D_{f,inh,n}$ = Nuclide specific dose conversion factor for internal dose from activity in inhalation (mSv/Bq)

$$D_{adult} = \sum_{n} A_n \left(D_{f,cl,n} + D_{f,gr,n} + D_{f,inh,n} \right)$$

Equation 2. Calculation of effective dose to adults *[43]*.

Table 19 shows the facilities and their highest effective dose (the upper limit) in the event of a fire based on calculation in accordance to [43].

Table 19. Calculated effective dose to adult in case of event of fire at Cyclife Sweden AB's facilities [37], [38], [39], [40], [41], [42].

Facility	Calculated effective dose to adult in case of fire (mSv)	
	200m	500m
Interim storage	5.98E-1	2.80E-1
SMA	1.57E-1	7.32E-2
SMA Annex	2,06E-1	1,34E-1
HA/DK	1.92E-3	8.91E-4
Pyrolysis	7.68E-3	3.6E-3
IKA	4.28E-2	2.01E-2

The assessed maximum exposure levels from the event of fire to adults, in the vicinity of the facilities are below 1 mSv, as shown in Table 19 above. There are also no exceptional pathways of exposure e.g., involving the export of foodstuffs. Therefore, data on exposure levels in other affected Member States are left uncomment.

6.3.2. Accidents entailing releases into an aquatic environment

No accidents or events are considered to lead to discharges into the aquatic environment [15], [44], [45], [46], [47], [48]. In an event where leakage of liquids with radioactivity content from the processes and facilities occurs, the liquid will be, as far as possible, collected and handled through the liquid waste treatment facility at SNAB. The exposure level for people and the surroundings to be expected far below 1 mSv due to the treatment within SNAB facility.

7. Emergency plans, agreements with other member states

Cyclife Sweden AB's plan for emergencies describes organization including available personnel with competence in relevant areas. Relevant areas are, e.g., managers, radiation physicists, and technicians. The emergency plan includes also alarm levels, instructions, instructions regarding communication with authorities and an evacuation plan. In a crisis situation, existing systems for dose rate and contamination control are used. Nuclide specific activity is analysed on samples taken by radiation protection personnel [49]. In additional to the internal emergency plan, Municipality of Nyköping has established an emergency plan for STP [50].

There are international and bilateral agreements and understandings on warning and information in the event of nuclear energy accidents. Sweden has signed the agreements e.g. The binding EU directive on early notification, and European Community Urgent Radiological Information Exchange (ECURIE). ECURIE requires that a warning must be given if measures are adopted for protection of the domestic population.

The Swedish Meteorological and Hydrological Institute (SMHI) is announced by notifications of accidents abroad. SSM is responsible for distributing the information within the country, and for sending information from Sweden in the event of a Swedish accident.

8. Environmental monitoring

The licensees are responsible for the analyses of the environmental monitoring according to [2]. Environmental monitoring has been performed at STP since 1957 and is still ongoing. Meteorological data are registered continuously, and the environmental monitoring also includes continuous monitoring of gamma activity in the surroundings. The results are reported to SSM. The authority also takes random samples for analysis to verify the results. The environmental monitoring program for STP is summarized in Table 20.

Table 20. Environmental monitoring programme for Studsvik Tech Park [51].

	Sample	Number of stations	Period (S = spring, A = autumn)
Terrestrial programme			
Natural vegetation	Moss	2	S, A
	Lichen	2	A
	Spruce sprouts	2	A
Cultivated vegetation	Lettuce	1	July
	Pasture grass	1	A
	Cereals	2	A
	Fruit (apple)	1	A
	Berries (currants)	1	A
Animal samples	Cattle	1	A
	Milk	1	Every fortnight during pasture season[18]
Sludge		3	A
Marine programme			
Water		1	Quarterly[16]
Sediment		5	S, A
Algae	Bladder wrack (or green algae)	5	S, A
	Diatomic algae	2	Monthly ice-free period
Molluscs & arthropods	Sea mussel	2	A
	Baltic mussel	2	A
Fish	Eel or perch	2	S, A
	Dab or eelpout	1	S, A
	Herring	1	S, A
	Pike	1	S, A

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