OSPAR COMMISSION

Swedish implementation report of OSPAR Recommendation 18/01 on radioactive discharges

Radioactive Substances Series

2021

OSPAR Convention The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Convention OSPAR La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. Les Parties contractantes sont l'Allemagne, la Belgique, le Danemark, l'Espagne, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède, la Suisse et l'Union européenne

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Content

Summary

The purpose of OSPAR Recommendation 18/01 on Radioactive Discharges is to apply the best available techniques (BAT) and the best environmental practice (BEP) in accordance with Appendices 1 and 2 of the OSPAR Convention to prevent and eliminate pollution caused by radioactive discharges from all nuclear industries including nuclear power plants, reprocessing facilities, fuel fabrication facilities, research reactors, and their associated radioactive waste treatment facilities and decommissioning activities.

According to the Recommendation 18/01 the Contracting parties shall report on implementation on this recommendation every six years in accordance with the Guidelines for the submission of Information about, and Assessment of, the Application of BAT and BEP in Nuclear Facilities (OSPAR Agreement 2018-01) using the format as set out in Appendix 1 to the Recommendation 18/01 as far as possible.

As so far there have been seven rounds of reporting according to PARCOM recommendation 91/4 (now superseded by OSPAR recommendation 18/01). Sweden has reported compliance with PARCOM Recommendation 91/4 during all seven implementation rounds. The first three reports from Sweden also included the Barsebäck nuclear power plant, which discharges in close proximity to the Convention waters.

This report concerns the implementation off BAT and BEP in the nuclear power plant at Ringhals (Ringhals NPP), the only Swedish nuclear facility concerned, in accordance with OSPAR Recommendation 18/01.

From the evaluations of the BAT/BEP indicators for discharges, environmental impact and radiation doses to the public it is concluded that BAT and BEP is applied at the Ringhals NPP during the time period covered by this report.

1. Introduction

The OSPAR Recommendation 18/01 concerns application of best available technique (BAT) and best environmental practice (BEP) in accordance with Appendices 1 and 2 of the Convention to prevent and eliminate pollution caused by radioactive discharges from all nuclear industries, including nuclear power plants, reprocessing facilities, fuel fabrication facilities, research reactors, and their associated radioactive waste treatment facilities and decommissioning activities. After 2019 Contracting Parties should report every six years on the implementation of this Recommendation in accordance with the guidelines.

The OSPAR Recommendation 18/01 supersedes the PARCOM Recommendation 91/4. Sweden has reported compliance with PARCOM Recommendation 91/4 during seven implementation rounds.

This report concerns the eight implementation round – the first according to the OSPAR Recommendation 18/01 – concerns the implementation of BAT and BEP at the nuclear power plant at Ringhals.

Ringhals NPP consists of one boiling water reactors (BWR), Ringhals unit 1, and three pressure water reactors (PWR), Ringhals unit 2-4. The units Ringhals 2 and Ringhals 1 have been taken out of operation in 2019 and 2020 respectively and will be decommissioned.

2. General information

2.1. Relevant national authorities and responsibilities

The Swedish Radiation Safety Authority (SSM) is the authority under auspice of the Swedish Ministry of the Environment with national responsibility within the areas of nuclear safety, radiation protection and nuclear non-proliferation. The SSM works proactively and preventively in order to ensure high levels of nuclear safety and radiation protection in the society.
The SSM has the mandate to issue regulations concerning nuclear safety and radiation protection for nuclear as well as non-nuclear activities. SSM is also responsible to conduct supervision and to control that licensees comply with applicable laws and regulations. Moreover, SSM is fully empowered to issue, with reference to safety, prohibitions and conjunctions combine.

2.2. National legislation

The Swedish Radiation Protection Act

The aim of the Radiation Protection Act (2018:396) is the protection of man and the environment against harmful effects of radiation.

The Radiation Protection Ordinance

The Radiation Protection Ordinance (2018:506) contains details pursuant to authorisation for the application of the Radiation Protection Act. The Ordinance authorises the SSM to act as the central administrative authority in the area of radiation protection and to issue regulations concerning radiation protection and environmental monitoring. The ordinance also contains dose limits and dose constraints.

The Environmental Code

The Environmental Code is a comprehensive legislation covering a wide range of environmental issues, including provisions on environmental impact assessments, licensing procedures, etc. The Code is applicable to activities generating ionizing radiation in the environment. Such activities are categorized as 'environmentally hazardous', together with numerous other activities.

Regulations issued by the SSM

On the basis of the authorisation granted in the Radiation Protection Ordinance, SSM has issued specific regulations concerning releases of radioactive substances from nuclear facilities "Regulations on the Protection of Human Health and the Environment from the releases of Radioactive Substances from Certain Nuclear Facilities" (SSMFS 2008:23). The regulations entered into force 1st February 2009, and was updated (SSMFS 2018:16). The regulations cover surveillance and monitoring, environmental programs and quality assurance.

SSM has also issued general radiation safety regulations for all licensed facilities (SSMFS 2018:1). These regulations cover e.g. methods for dose calculations to individuals in the general public and reporting and assessment of the radiation safety for the public and the environment.

2.2.1. Application of BAT/BEP in domestic legislation

The Radiation Protection Act stipulates that measures shall be taken to limit the generation of radioactive waste and emissions of radioactive substances as far as possible and reasonable, taking into account existing technical knowledge and economic and societal factors (chapter 3, section 9). In the explanatory text to the Act (Governmental Bill 2017/18:94) it is clarified that the requirement inter alia, refers to the agreements according to the OSPAR and HELCOM convention on the application of best available technique in order to limit radioactive discharges to the sea, but is also applicable to all emissions to water and sea from nuclear installations in Sweden. This paragraph aims mainly at the protection of the environment and should be used in parallel with the provisions on optimisation of radiation protection.

The Environmental Code includes requirements on that BAT should be applied in order to prevent, hinder or counteract harm or inconvenience to human health or the environment.

2.2.2. Dose limit, constraints and discharge limit setting rationale

According to *the Radiation Protection Ordinance* the dose limit for individuals of the general public, resulting from all practices, is 1 mSv annual effective dose. This is a requirement in EU BSS. An upper limit for dose restrictions for the public from individual practices is set to 0,1 mSv a year. There are no other general discharge limits. However according to the Swedish regulations on the Protection of Human Health and the Environment from the releases of Radioactive Substances from Certain Nuclear Facilities" (SSMFS 2008:23), the effective dose to an individual in the critical group from one year of releases of radioactive substances to air and water from all facilities located in the same geographically delimited area shall not exceed 0.1 mSv.

2.2.3. Regulation, surveillance and monitoring

Surveillance and monitoring of discharges of radioactive nuclides are regulated in Regulations on *the Protection of Human Health and the Environment from the releases of Radioactive Substances from Certain* Nuclear Facilities" (SSMFS 2008:23*).* The regulations entered into force 1st February 2009, and has been updated a couple of times since then.

2.2.4. Environmental monitoring programs

The Regulations on the Protection of Human Health and the Environment from the releases of Radioactive Substances from Certain Nuclear Facilities (SSMFS 2008:23) include provisions on environmental monitoring. According to the regulation monitoring shall be conducted in the surrounding areas of nuclear facilities in accordance with programs formulated by the Swedish Radiation Safety Authority. The programs contain regulations for sampling, sample preparation, analysis, evaluation and reporting as well as information on the type of samples and sample locations.

The environmental monitoring program is issued by the SSM (latest version, SSI Report 2004:15) and specifies type of sampling, sample treatment, radionuclides considered, reporting, etc. The site specific monitoring programs vary depending on the facility and are divided in a terrestrial and an aquatic part. The terrestrial part includes samples of natural and cultivated vegetation as well as food products like milk and meet. The aquatic part includes samples of seawater, sediment, fish, molluscs, arthropods macro and micro algae. The selection of environmental samples (biota and sediments) has been conducted in order to be highly representative of the area around the facility and to, preferably, be similar (or have a similar function in the ecosystem) for all facilities. Also some of the species have been selected because they are part of the human food chain. Every year a basic program involving spring and autumn sampling is conducted. Furthermore, certain samples are taken on a monthly and quarterly basis. In addition to the basic program, extended sampling is also conducted every fourth year at the most of the facilities. The extended program focuses exclusively on samples taken in the marine environment.

Sampling at and outside the facilities is generally performed by the National Board of Fisheries. The samples are analysed by the facilities themselves or by external laboratories which must have an adequate system for quality assurance. To verify that the facilities comply with the program, SSM performs inspections and takes random sub-samples for measurements at the SSM or at independent laboratories.

An evaluation of the environmental monitoring program was conducted by the former SSI in 1999–2000 (SSI-report 2000:13) and the program was extensively revised.

For all events resulting in an increased release of radioactive substances to the environment SSM has the mandate to request separate environmental monitoring and assessment of the environmental consequences to affected areas. In connection with increased releases or other abnormal situations, the facilities are responsible for conducting special investigations, if SSM so decides. The extent and design of these investigations is decided from case to case by the SSM on the basis of information on the type and size of the release, recipient, season and other factors that may be of importance. The results from such measurements shall, if the SSM does not decide otherwise, be reported to the SSM within one month after the final sampling.

Continuous measurements of gamma radiation in the environment around nuclear power reactors, research reactors or material testing reactors are also requested. Measurements shall be conducted within each 30° sector on land at a distance of about one kilometre from the facility.

The environmental dosimeters (thermo luminance dosimeters, TLD´s) are evaluated quarterly and the results are reported to SSM. Experiences show that the readings for radiation levels are on the same level as the background radiation. However, the dosimeters enable evaluation of the consequences of larger airborne releases that cannot be traced through measurements of samples (for example short-lived radioactivity and radioactive noble gases).

The meteorological conditions at nuclear power reactors, research reactors and material testing reactors shall be continuously recorded.

Meteorological data shall be documented at the nuclear power plants and the Studsvik facility. If the releases are of such a size that the most contaminated area must be determined, these data shall form the basis of the calculations.

2.2.5. Radiation dose assessment methods

Effective dose to the public is assessed using detailed, site-specific dose models (the PREDO platform). Dose is assessed using the concept of representative person (ICRP 101a) and dose is calculated for three different age-groups.

2.2.6. Environmental norms and standards

There is at present no established norms or standards for the protection of the environment. However, there are a number of international efforts on-going with the purpose to formulate a system, or framework, for the protection of the environment. The International Commission for Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA) and the United Nations Committee on the Effects of Atomic Radiation (UNSCEAR) have different roles in this work.

2.2.7. Quality assurance

According to *Regulations on the Protection of Human Health and the Environment from the releases of Radioactive Substances from Certain Nuclear Facilities" (SSMFS 2008:23)* surveillance and monitoring should be quality assured and documented according to relevant ISO-standard procedures. Also the laboratories involved are obliged to take part in proficiency tests on the demand of the SSM.

2.3. Nuclear Power Plant

Ringhals nuclear power plant, operated by Ringhals AB, is a subsidiary of Vattenfall AB.

2.3.1. Type of facility

Ringhals NPP consists of four reactor units:

- Ringhals unit 1: Boiling water reactor (BWR), ASEA Atom, Westinghouse Electric Sweden
- Ringhals unit 2-4: Pressurised water reactors, PWR (Westinghouse).

Ringhals unit 2 was permanently shut down in December 2019 and Ringhals unit 1 in December 2020, following a decision, in year 2015, to close the reactors five years earlier than originally planned for commercial reasons. Both reactor units are now under decommissioning. The facility also consists of auxiliary facilities for waste treatment, maintenance, etc. and a shallow land repository for low-level radioactive waste resulting from the operation of the plant.

2.3.2. Start and end of operations

The start and end of operations for the reactor units at Ringhals NPP are given in Table 2.4.

Table 2.4 *Start and end of operations (criticality and commercial operation) for the Ringhals reactor units*.

Unit	Type	Criticality, year	Commercial operation, year	Permanently offline (out of operation), year
1	BWR	1973	1976	December 2020
2	PWR	1974	1975	December 2019
3	PWR	1980	1981	In operation
4	PWR	1982	1983	In operation

2.3.3. Installed thermal effect

In 2003 Ringhals AB applied for a licence according to the Environmental Code. The application also included power uprates at all reactors at the site. The licence was issued in 2006 and power uprates have been performed at all four reactors according to the agreed action plan.

Table 2.5 *Installed thermal effect after uprates.*

	Installed (MW_t)
R1	2540
R2	2660
R3	3144
R4	3300

2.3.4. Production

The installed electric effect (MW_e) and the annual net electrical output (GW_ea) for the years 2008–2019 is given in Table 2.6.

Table 2.6 *Installed electrical effect and net electrical output, Ringhals units 1 – 4.*

Unit	**1**	**2**	**3**	**4**
Installed effect, MW_e	881	900	1063	1123
Year	**Net output, GW_ea**			
2014	0,628	0,491	0,925	0,765
2015	0,662		0,879	0,868
2016	0,742	0,794	0,845	0,947
2017	0,566	0,766	0,960	0,989
2018	0,754	0,765	0,925	0,993
2019	0,765	0,616	0,981	0,958

2.3.5. Location

The Ringhals nuclear power plant is located at the Swedish West Coast, approximately 50 km S Göteborg and 15 km N Varberg (se also Figure 4.1).

2.3.6. Receiving waters and catchment area

The plant discharges into Kattegat. There are two adjacent discharge points immediately at the coast line, one for reactor units 1-2, and one for the units 3-4. Emissions to air are predominantly made through the main stack of each reactor unit, i.e. from four emission points.

3. Discharges

3.1. Plan for the implementation of BAT

As Ringhals 1 and 2 are permanently taken out of operation and the systems for reduction and monitoring of discharges will gradually be adopted during the decommissioning according to a plan reviewed and approved by the Swedish Radiation Authority (SSM). The systems described in table 3.1 and 3.2 are still in place but as the reactors are not in operation and as the decommissioning proceeds, the need of some of the systems will desist. SSM is following this work during routine inspections and surveillance programs.

The original design lifetime of Ringhals unit 3 and 4 will expire in 2021 and 2023, respectively. The licence holder, Vattenfall AB plans to extend operation of both units for a total operational lifetime of 60 years each. On the request of Sweden, the International Atomic Energy Agency (IAEA) has conducted a Safety Aspects of Long Term Operation (SALTO) peer review. The initial SALTO mission to Ringhals unit 3 was carried out in 2018 and a follow-up mission was conducted in September 2020. The final report from the mission has not yet been published.

3.2. Systems in place to reduce, prevent or eliminate discharges

The liquid waste to be discharged is purified by particle filtration, evaporation and/or ion exchange. To reduce the processing efforts, the liquid waste is segregated according to contents of activity and chemicals (e.g. detergents and particles in floor drain). Low-level fluids are discharged without any further treatment. The judgement of how to treat the waste is based on calculated dose to the public rather than on the activity content. At the PWR-sites evaporation is used in the systems for recycling of boron. A summary of the systems in place to reduce, prevent or eliminate discharges to the marine environment is presented in Tables 3.1–3.4.

3.3. Efficiency of abatement systems

The efficiencies of the abatement systems in place in the four Ringhals units are summarised in tables 3.1–3.4.

The performance of the liquid waste handling systems depends of several factors related to the operational conditions of the plant. For example at the end-of-cycle large amounts of waste water has to be processed during short periods of time and this high flow causes less effective purification, while at the beginning-of-cycle the flow is low and the conditions are ideal for good purification. In the table the typical performance has been estimated as to represent the entire operational cycle.

All tritium produced in the plants is released to the environment, although not necessarily in the same year as it is produced.

Table 3.1. *Ringhals unit 1 - Systems in place to reduce, prevent or eliminate discharges and their efficiency. Ringhals unit 1 is permanently offline (out of operation) since the end of 2020.*

Abatement system/ Management	Into operation (Year)		Efficiency of abatement system		Comments
	Existing	Planned	Decont. Factor	Other measure of efficiency	
Discharges					
Particulate filtration	1974		2-4		Some streams of waste water contaminated by detergents are cleaned only by particulate filtration
Ion exchange filtration	1974		10-50		Incl. good particulate decontamination
Large buffer tanks to recycle water from the reactor pool	2008		10	Reduces the volume of water that has to be processed at peak and will indirectly improve decontamination	
Evaporator	2011				Investigation on waste treatment of evaporator concentrate. Refurbishment of and improve-ments on existing evaporator
Laundry	2011				Laundry is now moved to an external facility
Good housekeeping					
Emissions					
Delay tanks	1974			Delay time normally 6-12 hours with recombiners in operation	
Recombiners	1998			Volume reduction by a factor 5-10	
Changes in management or processes					
Non fuel-leakage operations policy	1995			Reduction of number of leaking fuel. No fuel leakages during 2001-2016 Very low levels of tramp uranium (below detection limit)	Step 1: Careful monitoring of fuel leakages and prompt actions upon occurrence. Step 2: Reduction of factors contributing to fuel damages e.g. cleanliness during maintenance work in and around fuel pools. Debris catchers in feedwater lines.
Control-rod policy	2008			Reduction of tritium leakage from control-rods	Optimal positioning of control-rods
Minimising air leakage into turbine systems	Ca 1996			Improved delay time by 2-3 times. This is necessary to obtain good effect of recombiners	A continuous work
Separation of waste streams for improved treatments.	Ca 2000			n.a.	E.g. drain sumps are cleaned in special campaigns rather than at instances of high flow.

Table 3.2 *Ringhals unit 2 - Systems in place to reduce, prevent or eliminate discharges and their efficiency. Ringhals unit 2 is permanently offline (out of operation) since the end of 2019.*

Abatement system/ Management	**Into operation (Year)**		**Efficiency of abatement system**		**Comments**
	Existing	**Planned**	**Decont. Factor**	**Other measure of efficiency**	
Discharges					
Particulate filtration	1974		2-4		
Ion exchange filtration	1974		5-10		
Cross-flow filtration in combination with different absorbers and resins	2003		>100		R&D system permanent. Partial flow only.
Emissions					
Decay tanks	1974		Normally all nuclides except Kr-85 have		
HEPA-filtration	1974		100%		
Changes in management or processes					
Non fuel-leakage operations policy	1995			Reduction of number of leaking fuel. No fuel leakages during 2005-2016 Low levels of tramp uranium	Step 1: Careful monitoring of fuel leakages and prompt actions upon occurrence. Step 2: Reduction of factors contributing to fuel damages e.g. cleanliness during maintenance work in and around fuel pools.
Program for pH- and red-ox operational control and oxidising system clean-up operation during shut-down.	Late 70s			Lowered dose rates on system surfaces	
All fuel that will be re-used in the reactor is cleaned from crud using ultra-sonics.	2015			Reduction of source term for activated radionuclides	
Separation of waste streams for improved treatments. Some highly contaminated waters are transferred to Ringhals 1 waste treatment plant.	Ca 2000			n.a.	

Table 3.3 *Ringhals unit 3 - Systems in place to reduce, prevent or eliminate discharges and their efficiency.*

Abatement system/ Management	Into operation (Year)		Efficiency of abatement system		Comments
	Existing	**Planned**	**Decont. Factor**	**Other measure of efficiency**	
Discharges					
Particulate filtration	1981		5-10		Improvements have been done to the system during 2007-2008
Ion exchange filtration	1981		10-50		
Emissions					
Decay tanks	1981		Normally all nuclides except Kr-85 has		Gas releases are dominated by a small volume flow from degassing of the charging pumps that is not collected to the decay tanks.
HEPA-filtration	1981		100%		
Delay of gas flow from degassing of Charging pumps	2013		10		Improved collection and delay of the dominating stream of noble gases emissions.
Changes in management or processes					
Non fuel-leakage operations policy	1995			Reduction of number of leaking fuel. No fuel leakages during 2004-2016 Very low levels of tramp uranium (below the detection limit)	Step 1: Careful monitoring of fuel leakages and prompt actions upon occurrence. Step 2: Reduction of factors contributing to fuel damages e.g. keeping clean during maintenance work and in and around fuel pools.
Separation off waste streams for improved treatments. Some highly contaminated waters are transfered to Ringhals unit 1 waste treatment plant.	1999		>10		
All fuel that will be re-used in the reactor is cleaned from crud using ultrasonics.	2015			Reduction of source term for activated radionuclides	
Program for pH- and red-ox operational control and oxidising system clean-up operation during shut-down.	Early 80s			Lower dose rates on system surfaces and less activity spread in plant.	
Activities with the aim to reduce Sb-124 in reactor Cooling system	2020-2021			Reduction of source term for Sb-124	

Table 3.4 *Ringhals unit 4 - Systems in place to reduce, prevent or eliminate discharges and their efficiency.*

Abatement system/ Management	**Into operation (Year)**		**Efficiency of abatement system**		**Comments**
	Existing	**Planned**	**Decont. Factor**	**Other measure of efficiency**	
Discharges					
Particulate filtration	1983		5-10		Improvements are done to the system during 2007-2008
Ion exchange filtration	1983		10-50		
Emissions					
Decay tanks	1983		Normally all nuclides except Kr-85		Gas releases are dominated by a small volume flow from degassing of the charging pumps that is not collected to the decay tanks.
HEPA-filtration	1983		100%		
Membran-filtration in the feed water system	2008-2009		>90% of Ar-41		Now permanently installed and in operation
Program for pH- and red-ox operational control and oxidising system clean-up operation during shut-down.	Since start 1983			Lower dose rates on system surfaces and less activity spread In plant	Now fully optimized pH regime following SG replacement.
Changes in management or processes					
Non fuel-leakage operations policy	1995			Reduction of number of leaking fuel. One fuel leakage occurred during the period. Very low levels of tramp uranium (below the detection limit)	Step 1: Careful monitoring of fuel leakages and prompt actions upon occurrence.Step 2: Reduction of factors contributing to fuel damages e.g. keeping clean during maintenance work and in and around fuel pools.
Program for pH- and red-ox operational control and oxidising system clean-up operation during shut-down.	Since start 1983			Lower dose rates on system surfaces and less activity spread in plant.	
All fuel that will be re-used in the reactor is cleaned from crud using ultrasonics.	2012			Reduction of source term for activated radionuclides	
Separation of waste streams for improved treatments. Some highly contaminated waters are transferred to Ringhals unit 1 waste treatment plant.	1999		>10		
Activities with the aim to reduce Sb-124 in reactor Cooling system	2020-2021			Reduction of source term for Sb-124	

3.4. Absolute discharges and trends

The absolute discharges of beta-emitters excluding H-3 and total alpha emitters (Bq/a) from reactor units 1 – 4 have remained stable or declined over the time period studied. Discharge data has been reported to the OSPAR Commission and is available through the Odims database: https://odims.ospar.org.

On the basis of experience, the operators have introduced more stringent regimes for preventing fuel failures, and for fuel replacement in the case fuel failures occur. The discharges have therefore in recent years returned to values more characteristic of long-term performance in the absence of fuel failures.

During the time period covered in this report (2014 – 2019), one fuel leakage was detected. The leakage occurred at Ringhals unit 4 in November 2014 and the fuel rod was removed in 2015. The leakage resulted in very small amounts of tramp uranium (at or below the limit of detection) and did not affect the discharges more than marginally.

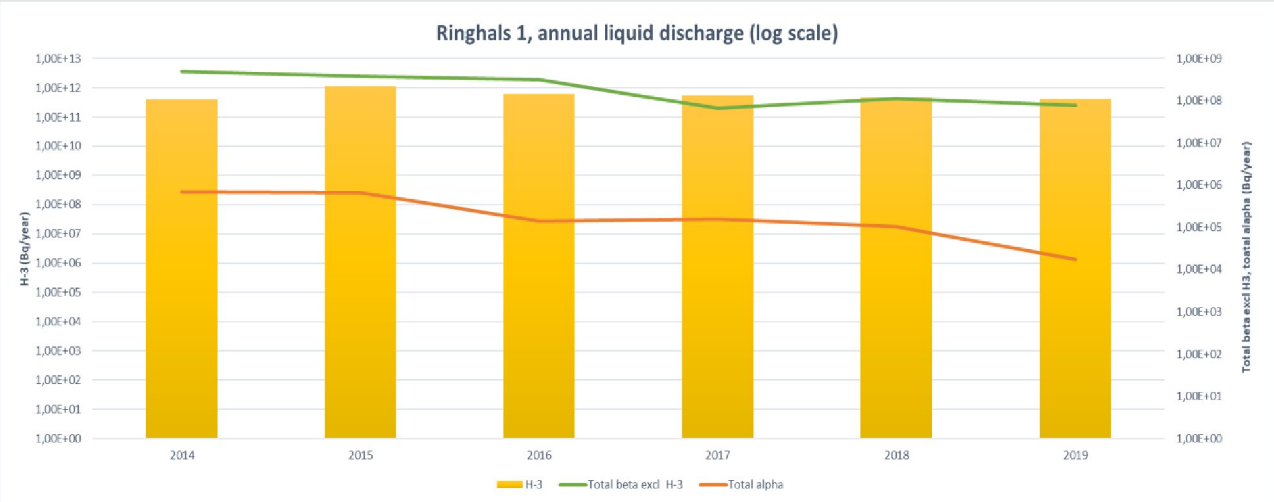

Figure 3.1. *Discharges of H-3, total beta excl. H-3 and total alpha from Ringhals unit 1 (Bq/year).*

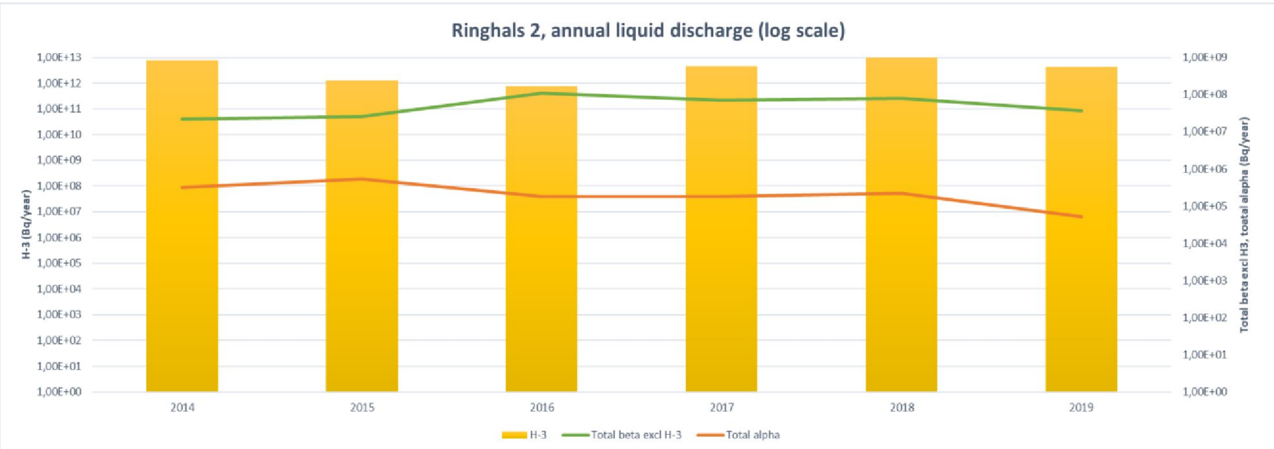

Figure 3.2 *Discharges of H-3, total beta excl. H-3 and total alpha from Ringhals unit 2 (Bq/year).*

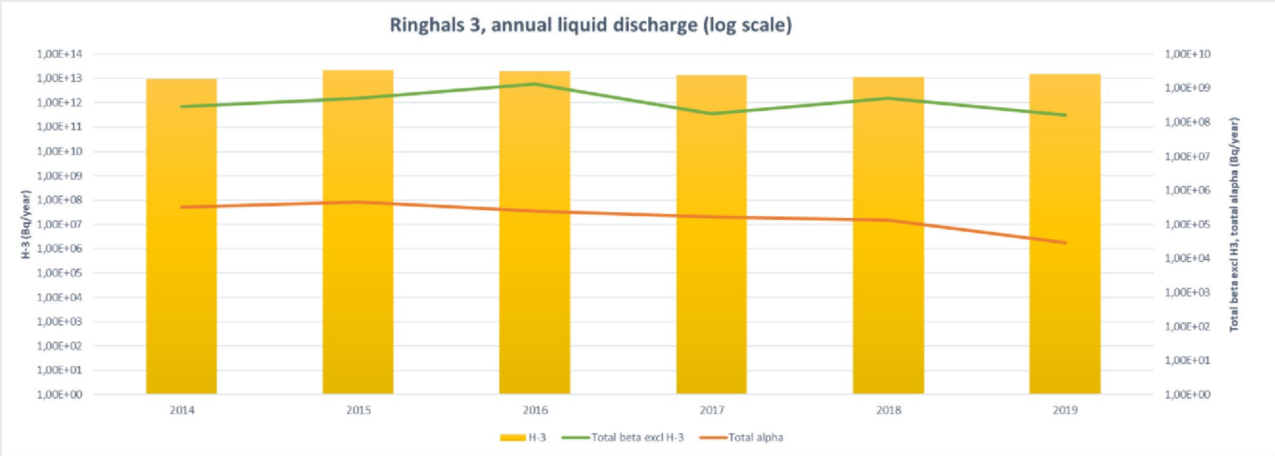

Figure 3.3 *Discharges of H-3, total beta excl. H-3 and total alpha from Ringhals unit 3 (Bq/year).*

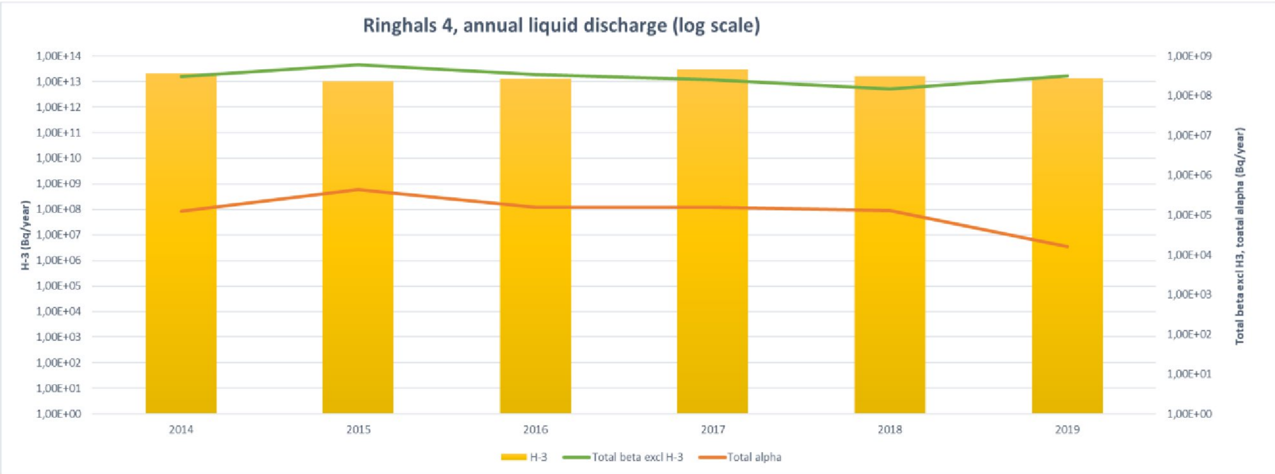

Figure 3.4 *Discharges of H-3, total beta excl. H-3 and total alpha from Ringhals unit 4 (Bq/year).*

3.4.1. Site-specific target discharge levels

For nuclear power reactors site-specific target discharge levels are used as a tool for applying BAT. These levels are called reference levels and target levels. The reference level should show ”*the release level that is representative for optimum handling and full functioning of systems of importance to the origin and limitation of radioactive releases from a nuclear power reactor*”. Decisive factors for defining reference levels are operating experience and knowledge of the size of releases, in a historical perspective. Reference levels can also comprise indicators of the efficiency of the effluent treatment systems. The reference levels will be different for different reactors. It is important to point out that these levels are considered to be measures of the normal abatement capability of different reactors. The levels can consequently be changed, for example, when there is a change in abatement systems. Taking the BAT concept into consideration, the facility shall also establish target levels for each nuclear power reactor. The target level should show “*the level to which the radioactive releases from nuclear power reactors can be reduced during a certain given period of time*”.

For the reactors at the Ringhals NPP, the target values for discharges and the resulting discharges are shown in table 3.5.

Table 3.5 Target values for discharges from Ringhals units 1-4, and the monitored discharges for 2014 -2019

Unit	Rad.nuclide	2014	2015	2016	Target Value 2016	2017	2018	2019	Target value 2020
R1	Co-58	4,8E+07	4,8E+07	1,8E+07	1,6E+08	2,5E+6	9,4E+6	8,1E+06	1,0 E+8
	Co-60	1,8E+08	1,4E+08	8,4E+07	3,5E+08	2,4E+7	4,1E+7	4,2E+7	1,0 E+8
	Cs-137	3,1E+07	8,7E+07	6,5E+07	6,2E+07	9,2E+6	2,5E+6	2,2E+6	2,0E+7
R2	Co-58	2,6E+06	0,0E+00	0,0E+00	1,0E+08	6,1E+6	1,22E+7	3,4E+6	1,0 E+8
	Co-60	1,4E+06	5,6E+06	6,9E+06	5,0E+07	6,6E+6	4,0E+6	5,5E+6	5,0E+7
	Cs-137	8,0E+05	1,0E+06	1,7E+06	1,0E+07	9,7E+5	1,1E+6	7,7E+5	1,0E+7
	Sb-124	0,0E+00	0,,0E+00	6,4E+04	5,0E+07	2,2E+7	3,0E+7	6,2E+6	5,0E+7
R3	Co-58	9,3E+07	9,8E+07	5,2E+07	2,4E+08	2,4E+7	7,0E+7	3,7E+7	2,0E+8
	Co-60	1,5E+08	1,5E+08	1,5E+08	3,0E+07	1,0E+7	1,9E+7	6,3E+6	3,0E+7
	Cs-137	7,6E+06	7,6E+06	7,6E+06	3,5E+06	1,8E+5	8,9E+4	2,3E+5	2,0E+6
R4	Co-58	3,8E+09	3,8E+09	3,8E+09	5,0E+08	7,9E+7	6,4E+7	1,6E+8	4,0E+8
	Co-60	1,2E+08	1,2E+08	1,2E+08	3,0E+07	7,5E+6	3,5E+6	4,6E+6	3,0E+7
	Cs-137	7,6E+06	7,6E+06	7,6E+06	3,5E+06	1,4E+6	4,2E+5	6,6E+5	2,0E+6

The rationales for choosing Co-60 and Cs-137 for reference and target values for discharges are the following. Co-60 is the dominating long-lived radionuclide in the discharges. It is also mainly discharged as particulates and as such an indicator of the efficiency of the system for particulate filtration. For the second period also Co-58 was included as a suitable reference radionuclide. The sources for the presence of Cs-137 in the discharges are free uranium on the core and leakage from old fuel in the fuel storage tanks. Cs-137 is mainly in a soluble form and an indicator of ion exchange filtration. The Ringhals unit 2 has a large fraction of Sb-124 present in the discharges which is the reason why this radionuclide is chosen. The source of this Sb-contamination has in spite of large efforts not been identified. For Ringhals unit 2 the target value for 2020 is the same as for 2016 despite of the fact that unit 2 is not in operation. The target values for up-coming years will be adjusted to better reflect this.

Annual discharges and target values are also shown figure 3.5 -3.16 below.

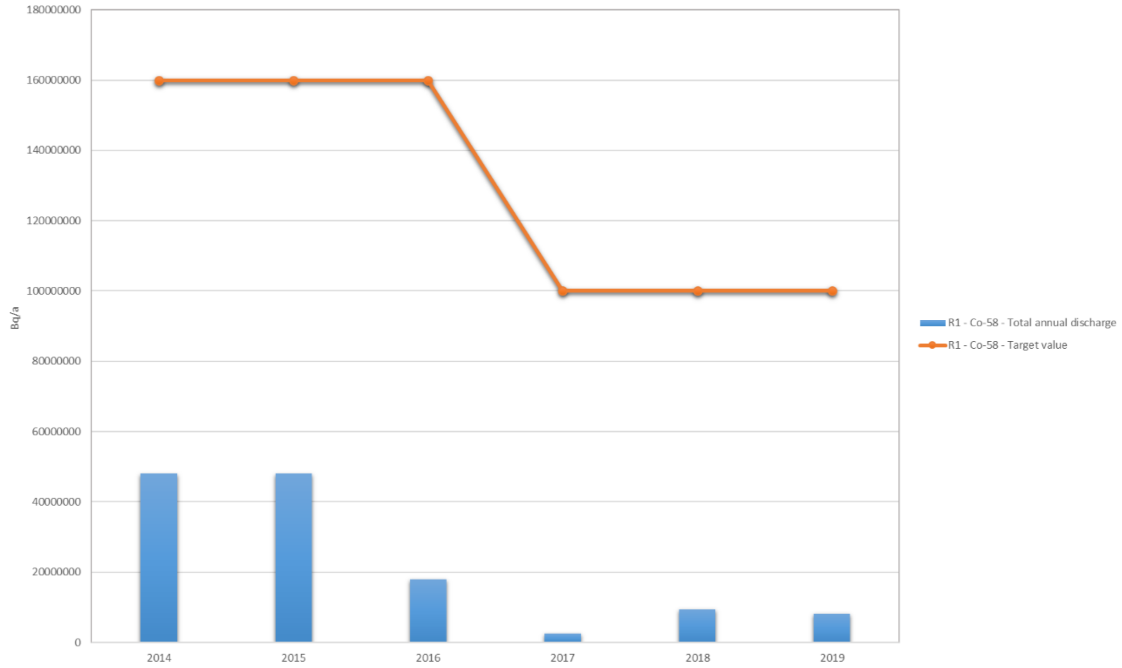

Figure 3.5 *Discharge of Co-58 from Ringhals unit 1, target level value and annual discharge.*

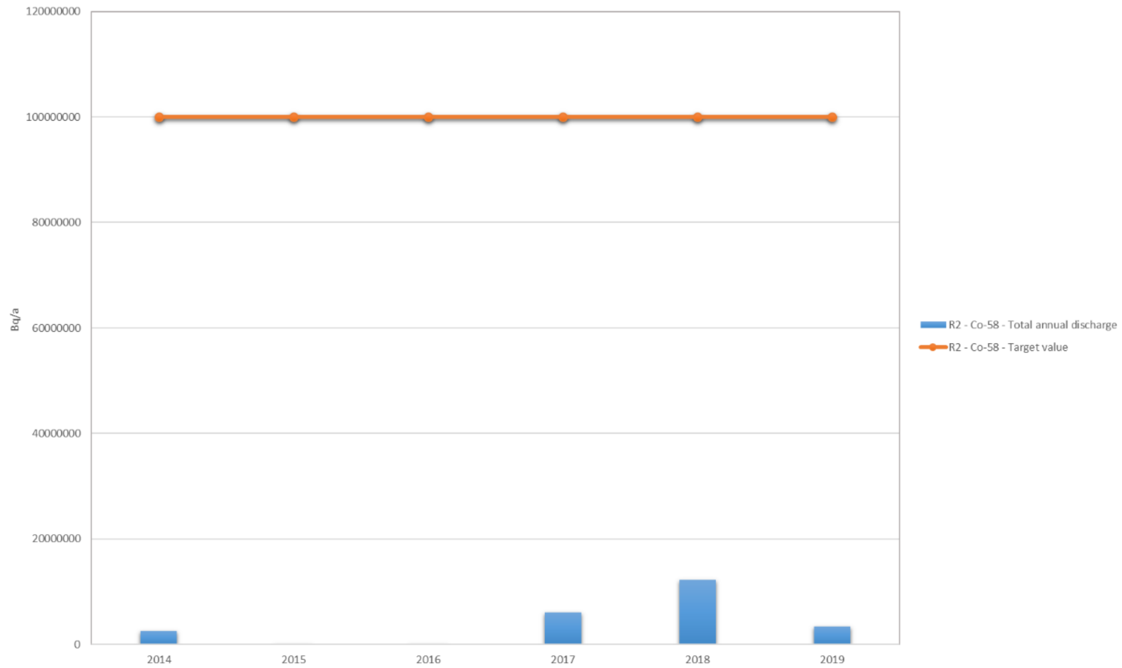

Figure 3.6 *Discharge of Co-58 from Ringhals unit 2, target level value and annual discharge.*

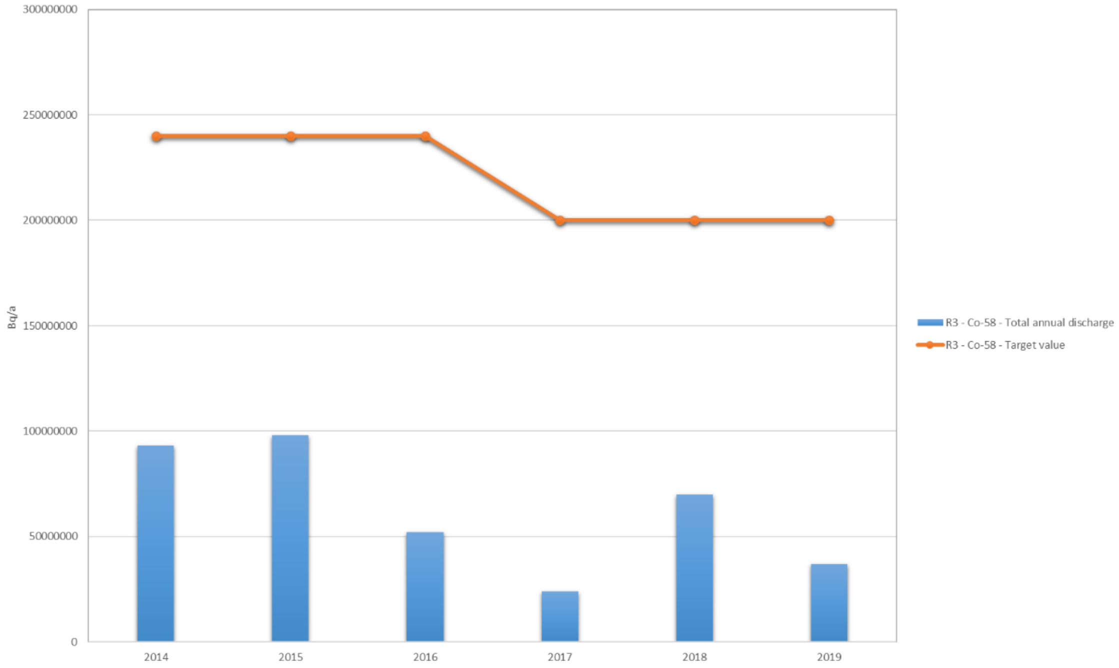

Figure 3.7 *Discharge of Co-58 from Ringhals unit 3, target level value and annual discharge.*

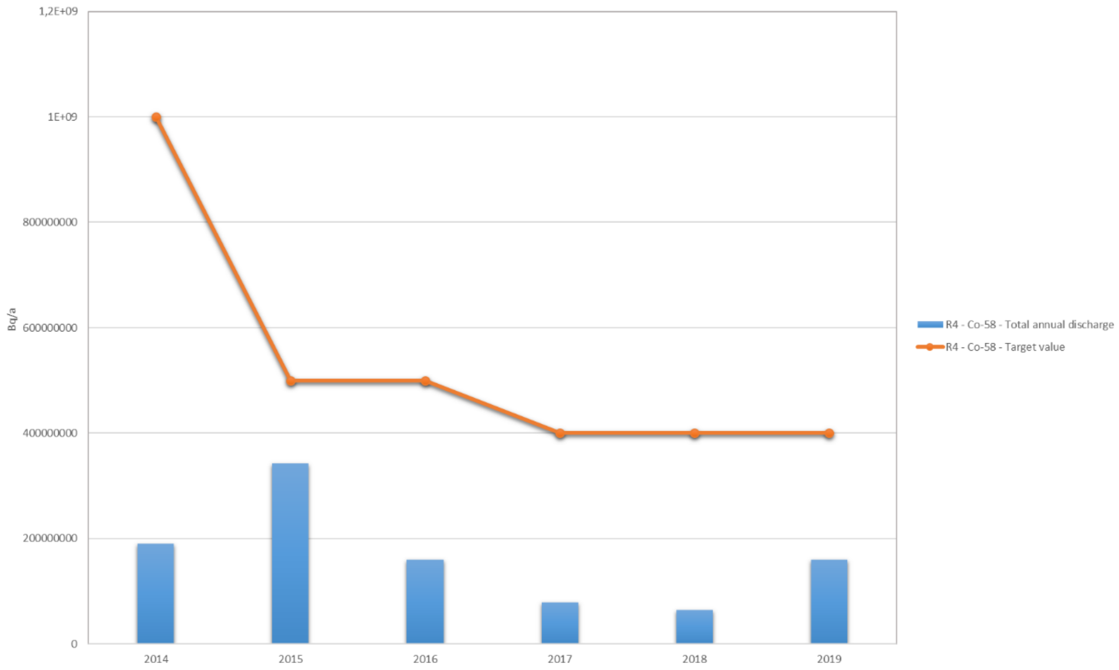

Figure 3.8 *Discharge of Co-58 from Ringhals unit 4, target level value and annual discharge.*

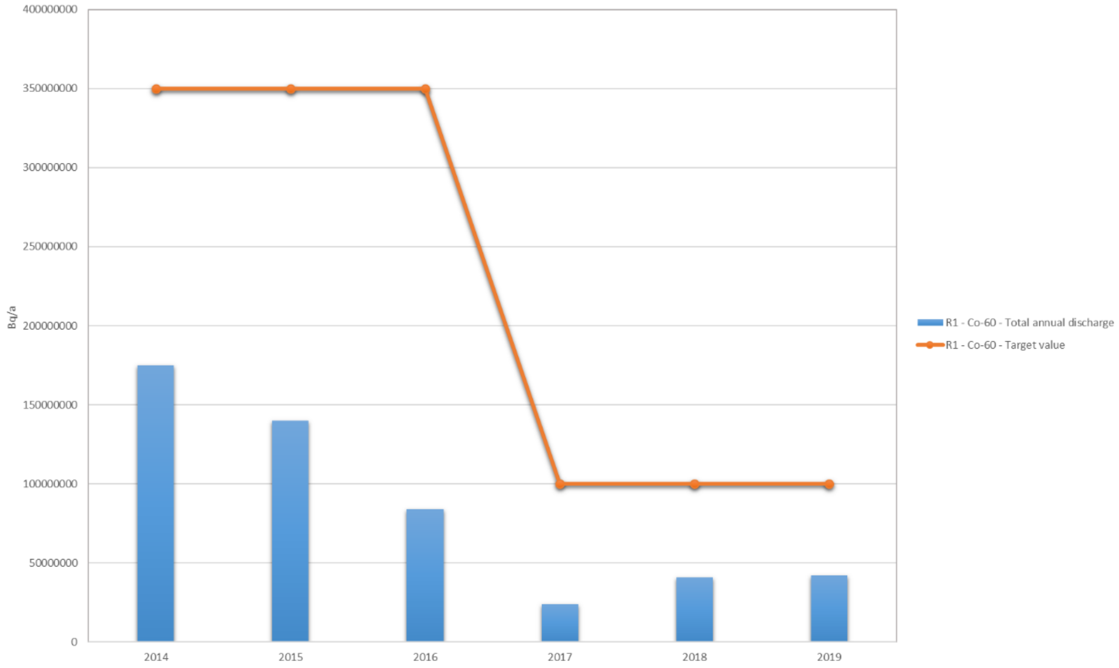

Figure 3.9 *Discharges of Co-60 from Ringhals unit 1, target level value and annual discharge.*

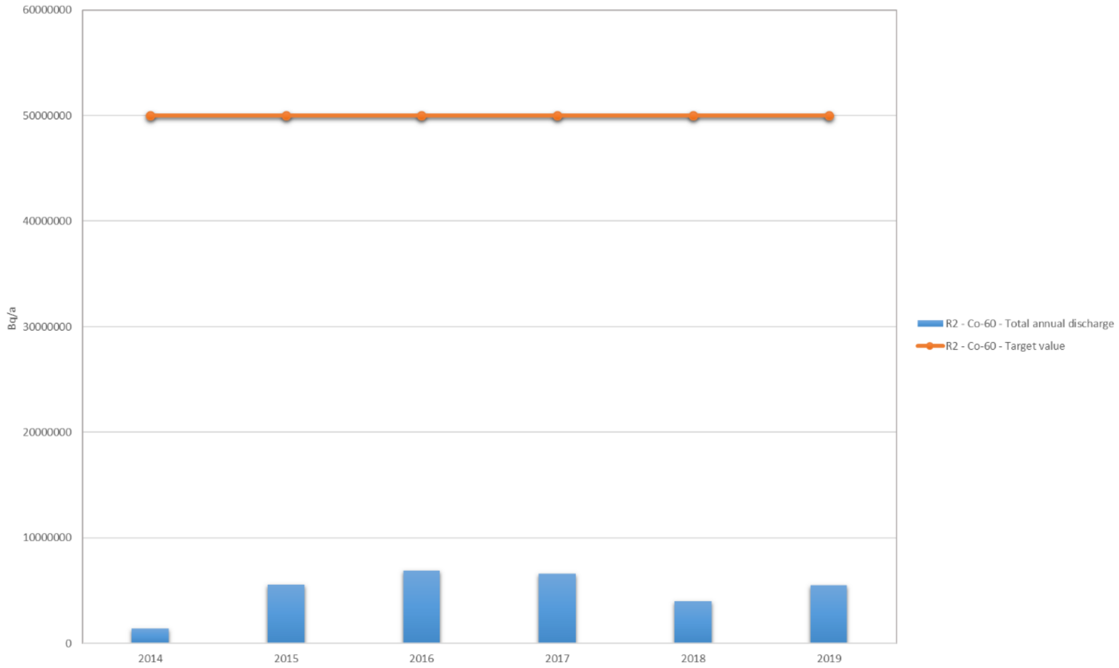

Figure 3.10 *Discharges of Co-60 from Ringhals unit 2, target level value and annual discharge.*

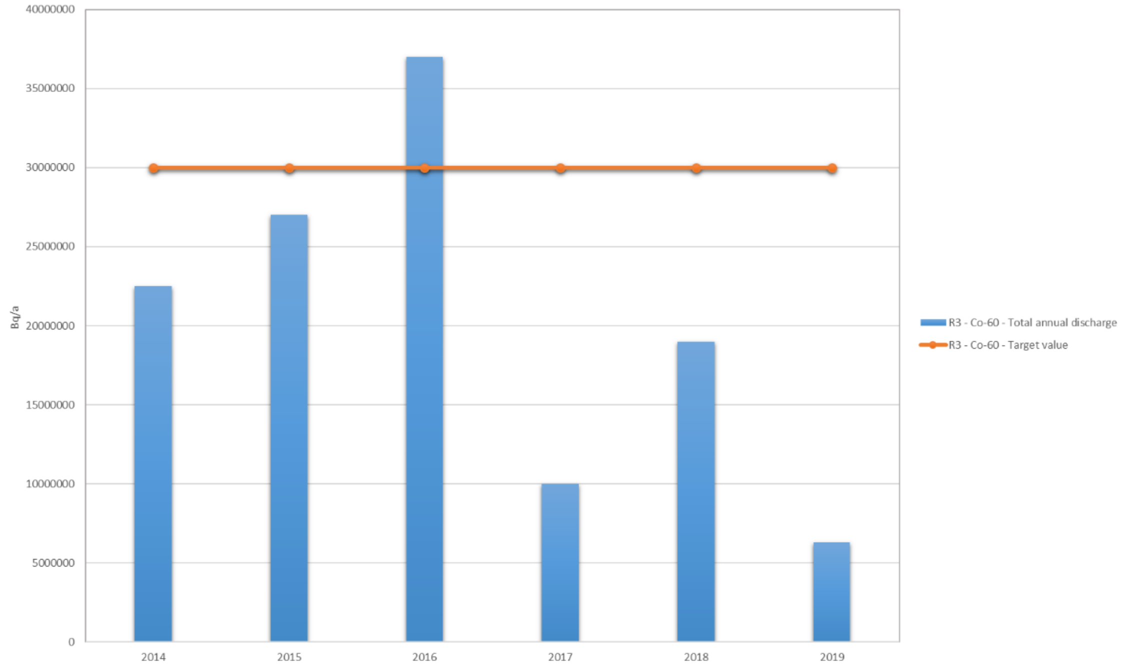

***Figure 3.11** Discharges of Co-60 from Ringhals unit 3, target level value and annual discharge.*

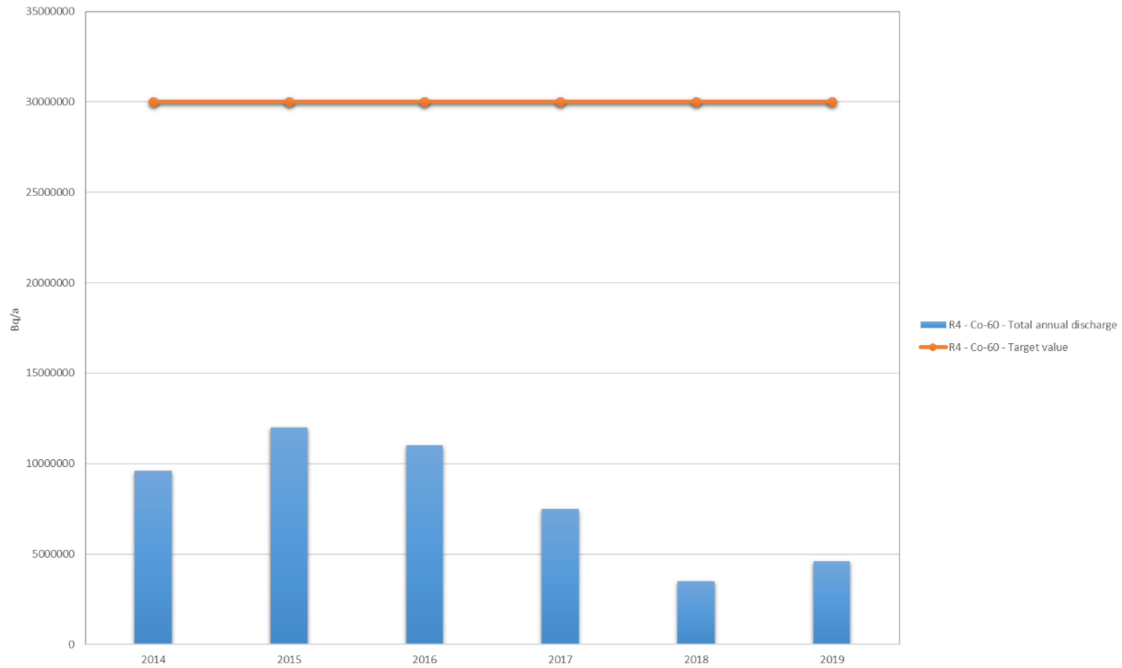

***Figure 3.12** Discharges of Co-60 from Ringhals unit 4, target level value and annual discharge.*

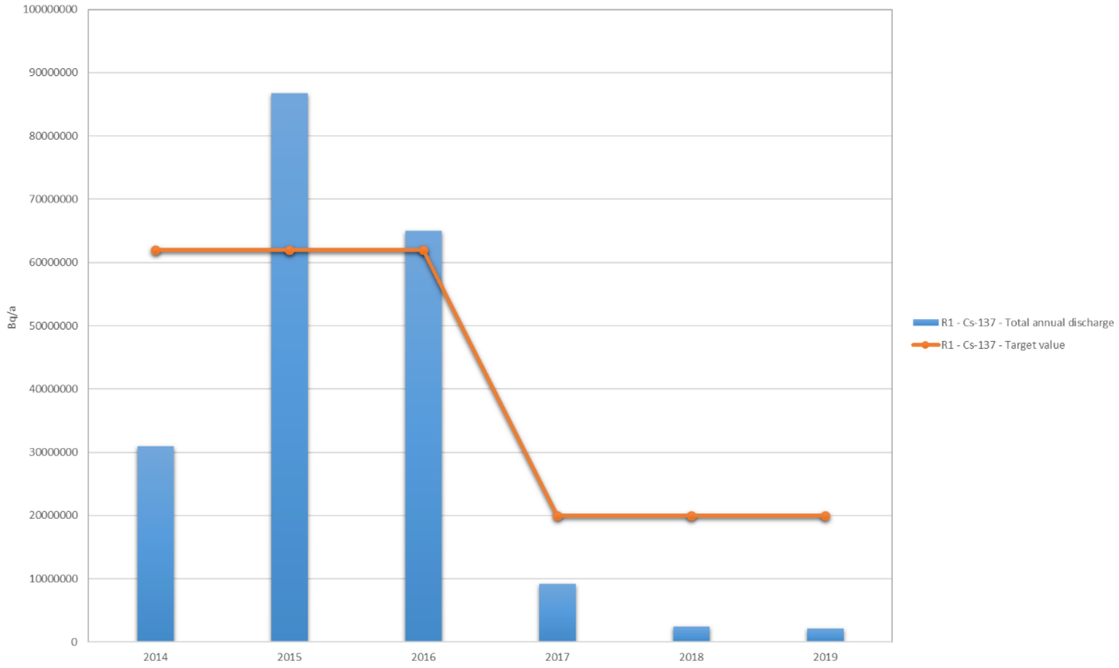

Figure 3.13 *Discharges of Cs-137 from Ringhals unit 1, target level value and annual discharge.*

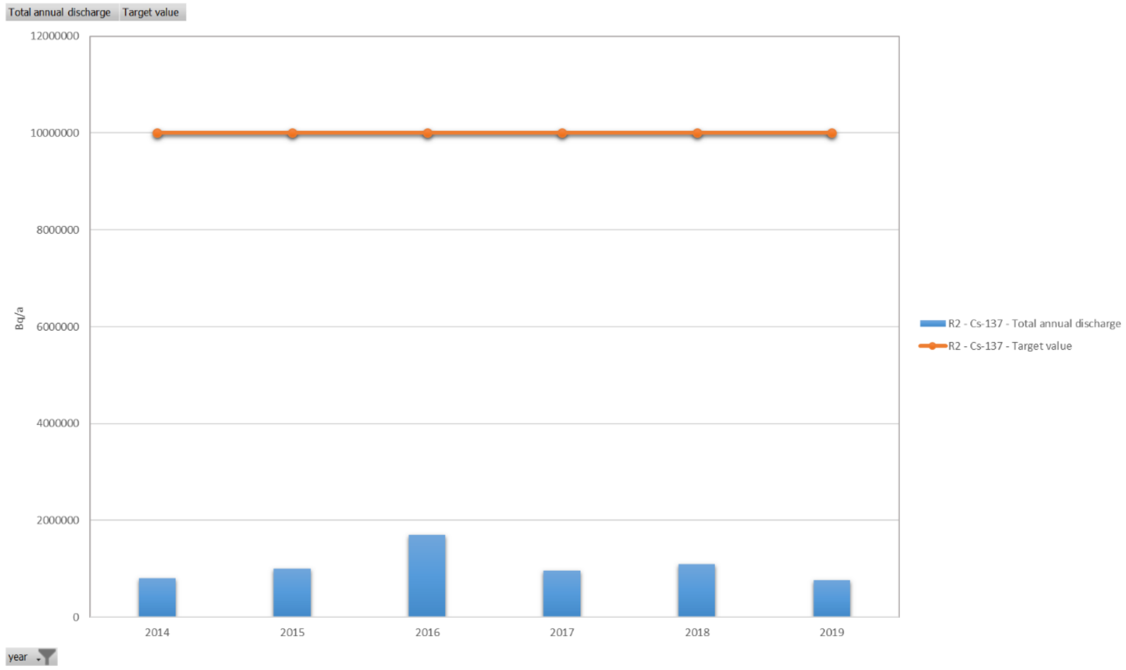

Figure 3.14 *Discharges of Cs-137 from Ringhals unit 2, target level value and annual discharge.*

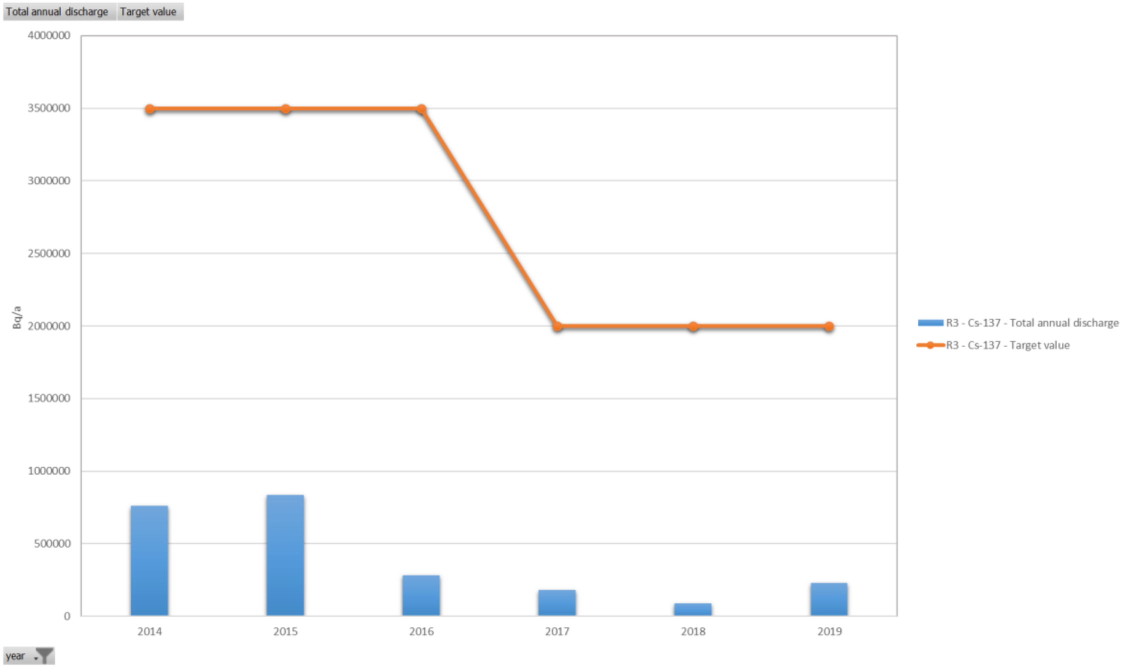

Figure 3.15 *Discharges of Cs-137 from Ringhals unit 3, target level value and annual discharge.*

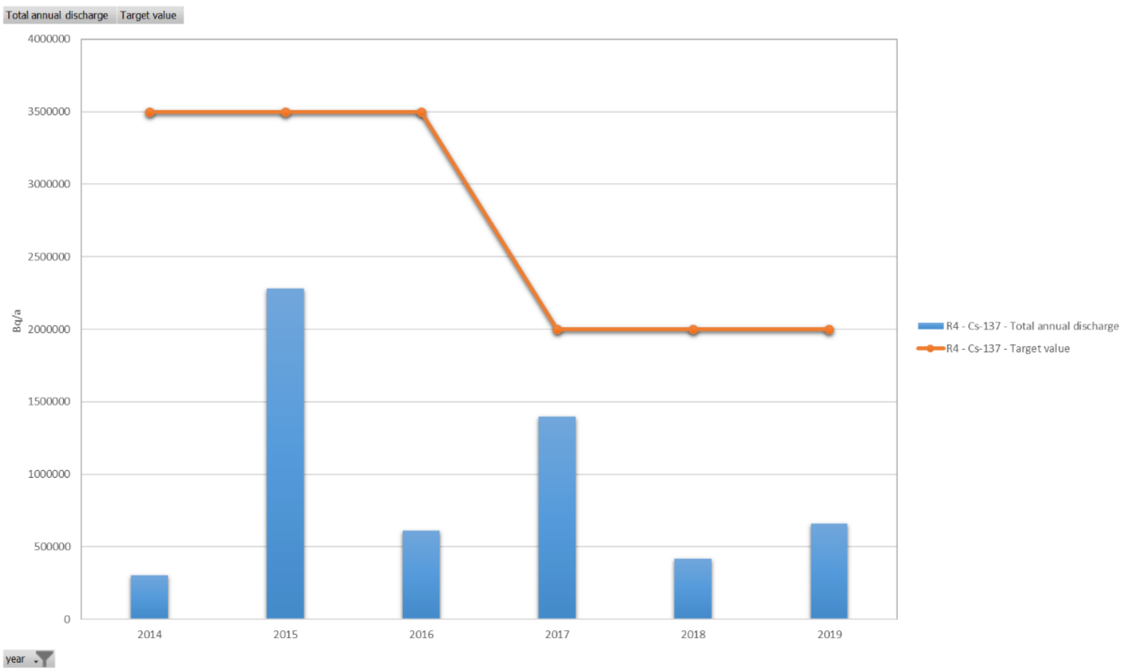

Figure 3.16 *Discharges of Cs-137 from Ringhals unit 4, target level value and annual discharge.*

3.4.2. Normalised discharges

Normalisation of discharge data can be a way of comparing discharges between sources of a similar kind. For nuclear power reactors, the discharge data are normalised with regard to net electrical output on an annual basis. These normalised discharges can then be compared with the mean global value for all reactors of the same type based on data published by UNSCEAR. Normalised mean global discharges of H-3 and “other” radionuclides from UNSCEAR 2016 are presented in table 3.6. In Figure 3.17-3.22, normalised discharges (in TBq/GWa) of total beta, total alpha and H-3 from Ringhals unit 1 and 2-4, is presented, and for total beta and H-3 compared with the global mean value for normalised discharges from UNSCEAR, 2016. In order to make the comparison the term "*total beta*", used in the Ospar context, is assumed to correspond to the term "*others*" used by UNSCEAR.

Table 3.6 *Global mean values for annual discharges of tritium (H-3) and "other" radionuclides from BWRs and PWRs,based on UNSCEAR 2016 data.*

Reactor type	UNSCEAR 2016 H-3 (TBq/GWa) Global mean value	UNSCEAR 2016 Other radionuclides (Tbq/GWa) Global mean value
BWR	0,82	0,0021
PWR	18	0,0038

Comparisons are only meaningful on the basis of long-term performance. Fluctuations between individual years may be large due to long outages (which reduce output but not necessarily discharges), transient phenomena, or irregular discharges. Values well above global mean may indicate that BAT is not applied for a specific source, whereas values close to or below the global mean may indicate that BAT has been applied.

The normalised discharges of beta-emitters excluding H-3, H-3 and total alpha emitters (TBq/GWa) from Ringhals unit 1 (BWR) and for Ringhals units 2, 3 and 4 (PWRs) have remained stable or declined over the time period studied as indicated in Figures 3.17-3.22. The normalised discharges of H-3 from Ringhals NPP are compared with a global mean value for normalised discharge of total H-3 from UNSCEAR, 2016 (Figure 3.17 and 3.22).

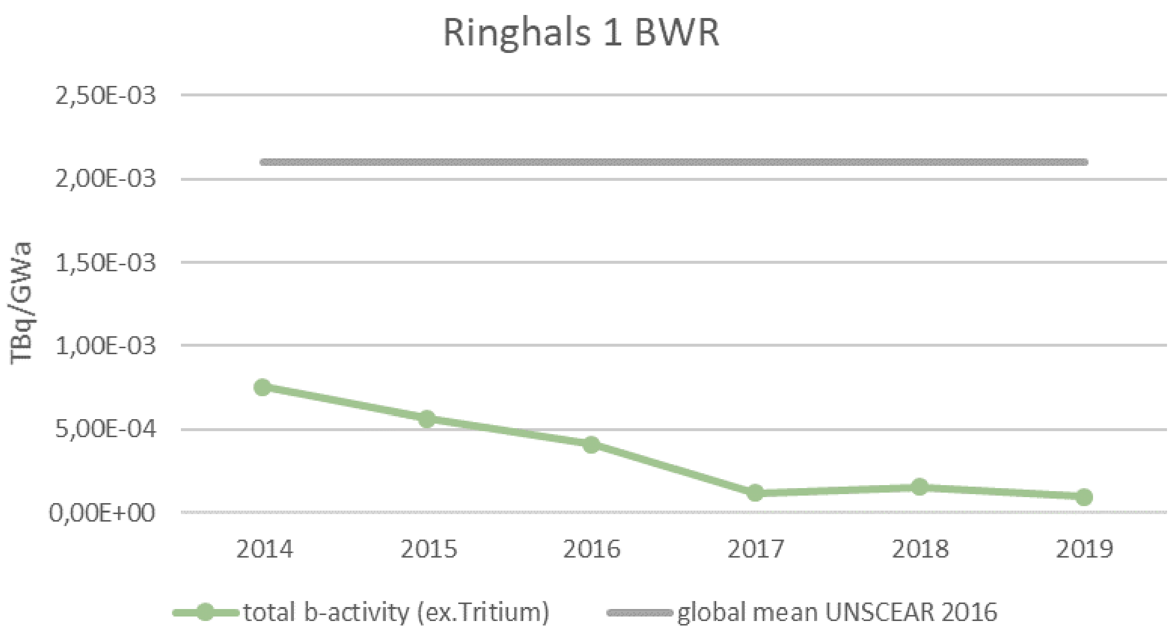

Figure 3.17 *Normalised discharges from Ringhals unit 1 for total beta exclusive H-3 (TBq/GWa), compared with data from UNSCEAR 2016 ("other" radionuclides).*

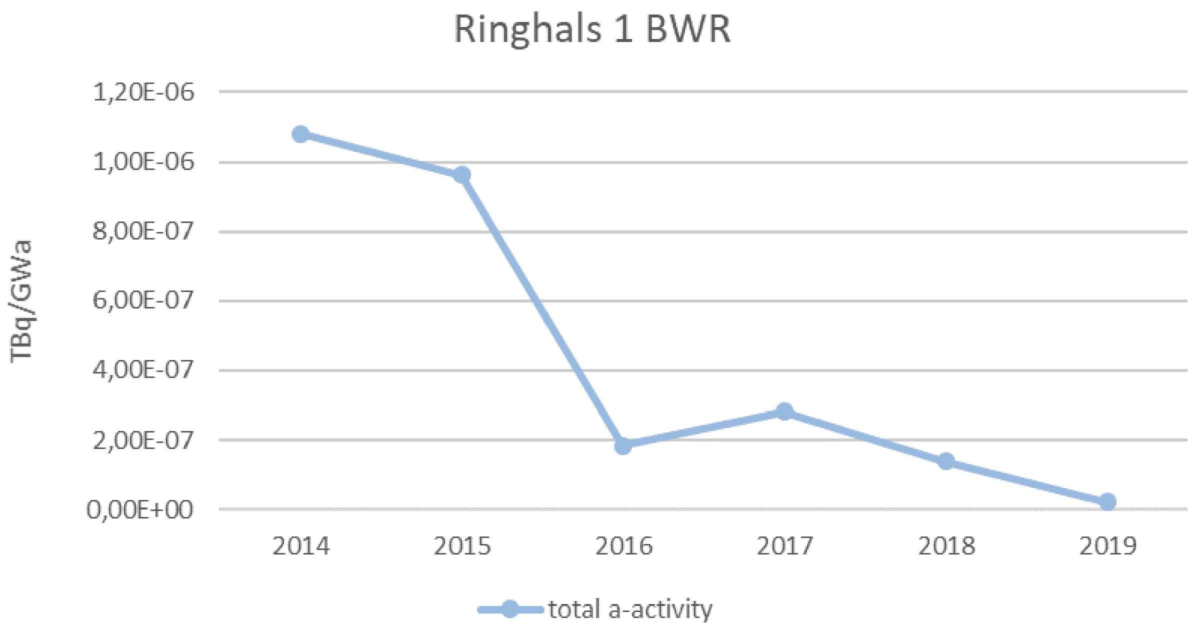

Figure 3.18 *Normalised discharges from Ringhals unit 1 for total alpha (TBq/GWa).*

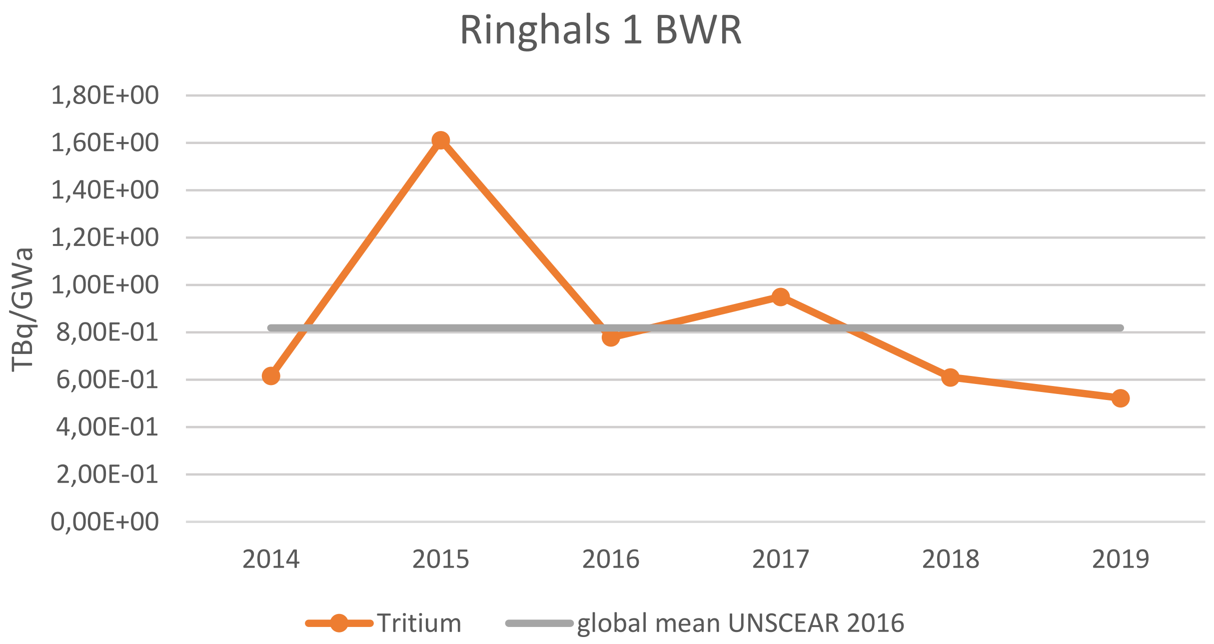

Figure 3.19 *Normalised discharges from Ringhals unit 1 for H-3 (TBq/GWa), compared with data from UNSCEAR 2016.*

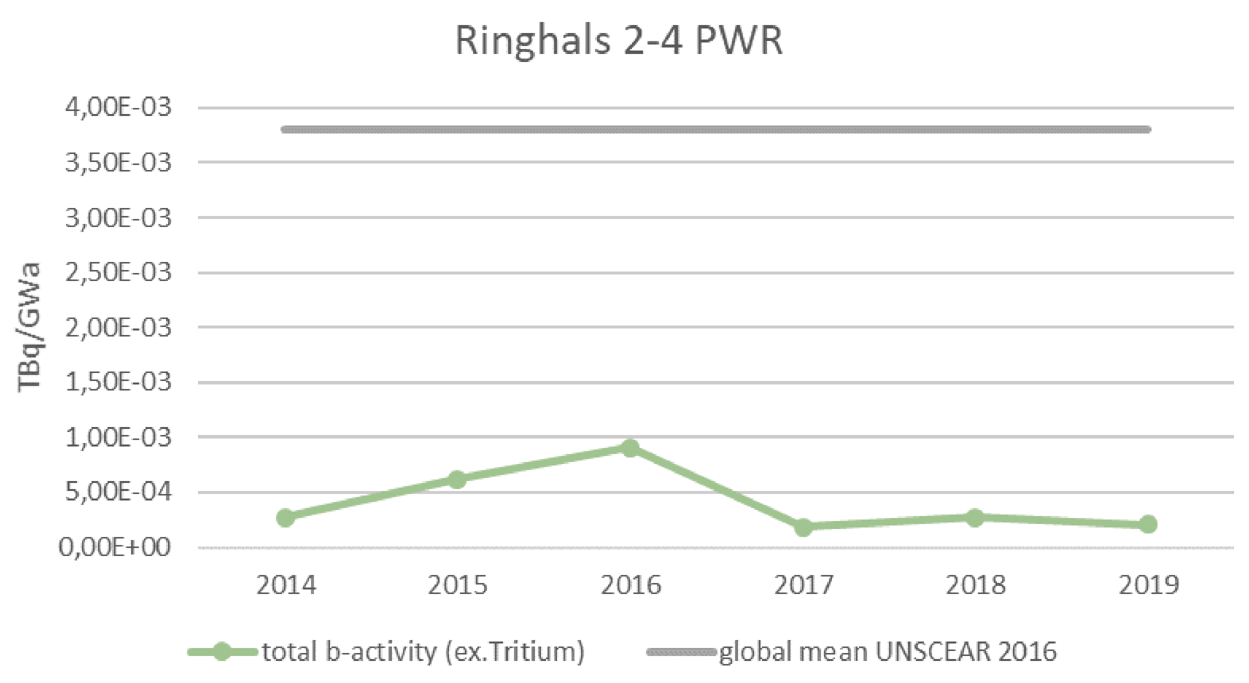

Figure 3.20 *Normalised discharges from Ringhals unit 2-4 for total beta exclusive H-3 (TBq/GWa) compared with data from UNSCEAR, 2016 ("other" radionuclides).*

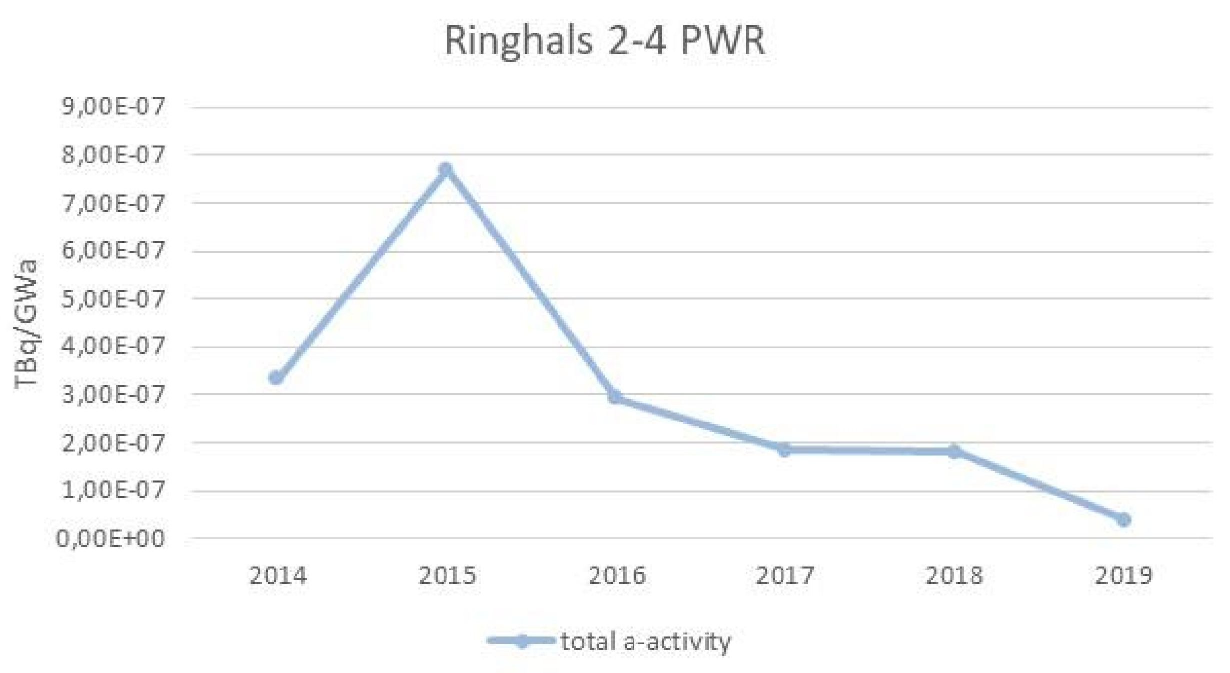

Figure 3.2*1 Normalised discharges from Ringhals unit 2-4 for total alpha (TBq/GWa).*

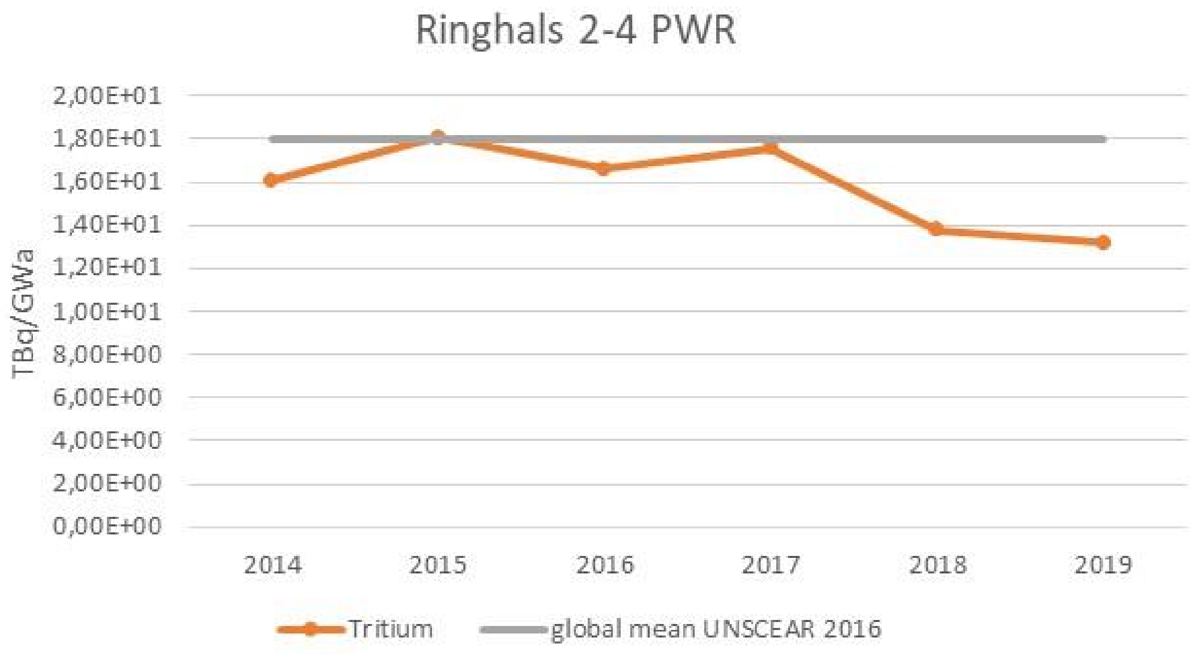

***Figure 3.22** Normalised discharges from Ringhals unit 2-4 for H-3 (TBq/GWa) compared with data from UNSCEAR, 2016.*

3.4.3. Quality assurance - discharges

Ringhals AB is certified according to ISO 14001 and EMAS. Equipment involved in quantification of discharges and emissions are calibrated regularly against traceable standards. Radiochemical analyses are checked in national and international inter-calibration exercises.

Specifically, the function of the retention systems is verified by radiometric analysis of samples of the treated solutions prior to discharge. If the concentration is below a certain (low) level compared to a standard solution of Co-60, the batch is discharged. If the value is above this level, it is analysed gamma-spectrometrically, and the dose contribution to the critical group is calculated. If the expected dose is below target levels for the unit, the batch is discharged. If not, it is sent for further treatment.

Data from treatment and discharge of the batches are kept manually in books. Data from the radiochemical analysis are kept in a computerised database, where additional data regarding volumes discharged also are stored. The site-specific target discharge values form the bases of the operational discharge control through derived target values that applies for each plant discharge system for each individual discharge tank. Levels above his derived values have to be authorised for discharge at an higher level of management.

3.4.4. Other relevant information

There is no other relevant information.

3.4.5. Data completeness and compliance

Data submitted have been complete in all aspects where the format is relevant.

3.5. Summary evaluation - Discharges

The following Table 4.9 summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on discharges from all reactor units at the Ringhals NPP.

Table 4.9 *Summary Evaluation of Discharges*

Criteria	**Evaluation**
The BAT/BEP indicators	
• Relevant systems in place	Yes, Management and technical systems improved since the start of the reactors
• Abatement factor	According to what is normal for the existing abetment systems
• Downward trend in discharges	Constant or downwards
• Downward trend in normalized discharges	Constant or downwards
• Comparison with UNSCEAR data	Within or below the range of available UNSCEAR data
• Downward trends in emission	Not for H-3 and C-14
• Relevant and reliable quality assurance	Yes
• Relevant site specific discharge values	Yes
• Data completeness	Complete
• Causes for deviations from indicators	No deviations identified
• Uncertainties	No influence on the conclusions
• Other information	None

4. Environmental impact

The environmental monitoring program is described in section 2.2.4. The program covers biotic and abiotic parts in the aquatic and terrestrial environments. In Figure 4.1 the environmental sampling stations reported to Ospar is presented. In region 11 North Sea Sweden has two sampling stations (SW7 Väderöarna and Fjällbacka), the rest of the Swedish stations are located in region 12 Kattegatt.

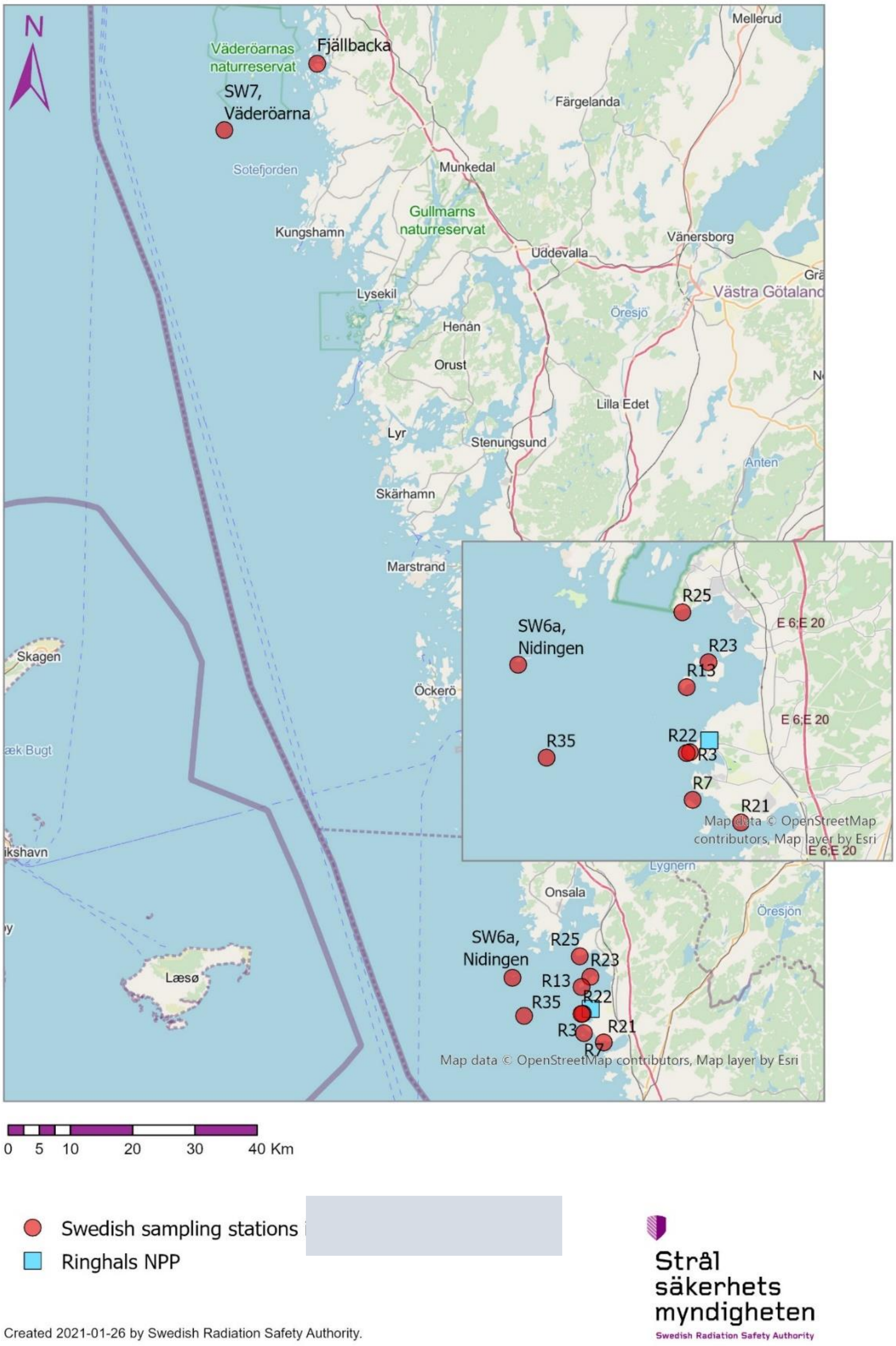

Figure 4.1 *Swedish sampling stations in region 11 North Sea and 12 Kattegatt of the Ospar area.*

4.1. Concentrations of radionuclides of concern in environmental samples

Concentration data from the environmental monitoring program has been reported to the OSPAR Commission and is available through the Odims database: https://odims.ospar.org.

Below are examples of radionuclide measurements in seawater, blue mussel (*Mytilus edulis*) figure 4.2, bladder wrack (*Fucus vesiculosus*) figure 4.3 and eel (*Anguilla Anguilla*) in figure 4.4.

The concentrations of Cs-137 in mussels, bladder wreck, and eel are given in wet weight. The results show a declining trend or stable levels during the examined time period.

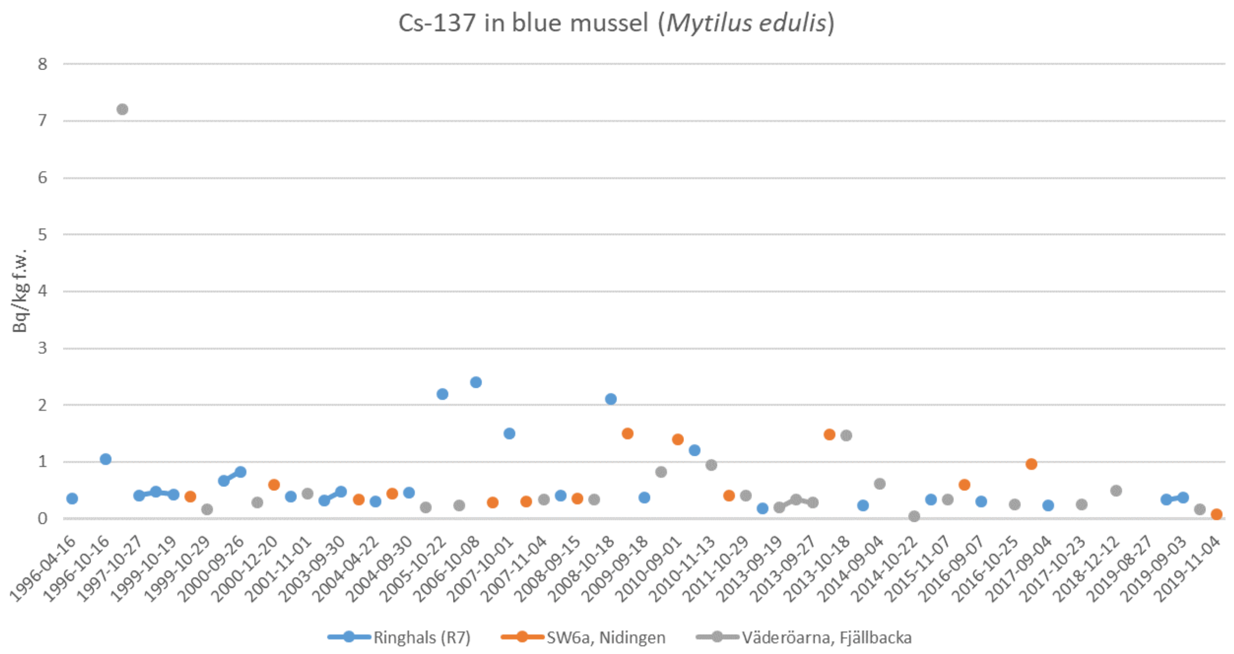

Figure 4.2 *Concentration of Cs-137 in blue mussels (Mytilus edulis) at the Swedish sampling stations in Bq /kg f.w.*

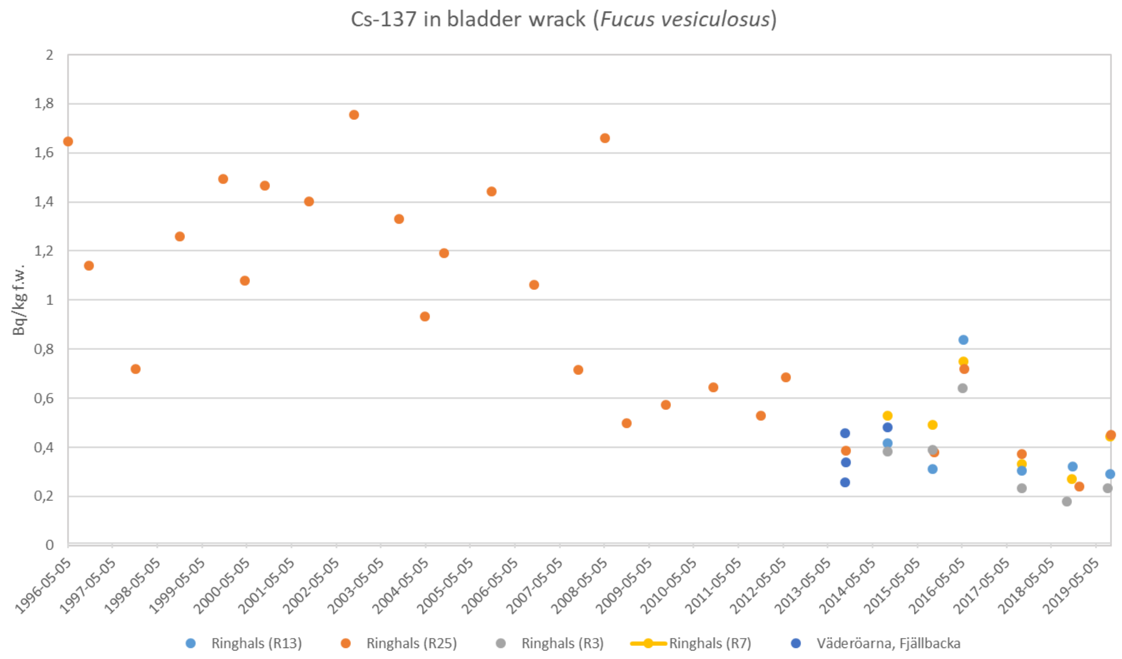

Figure 4.3 *Concentration of Cs-137 in bladder wrack (Fucus vesiculosus) at the Swedish sampling stations in Bq /kg f.w.*

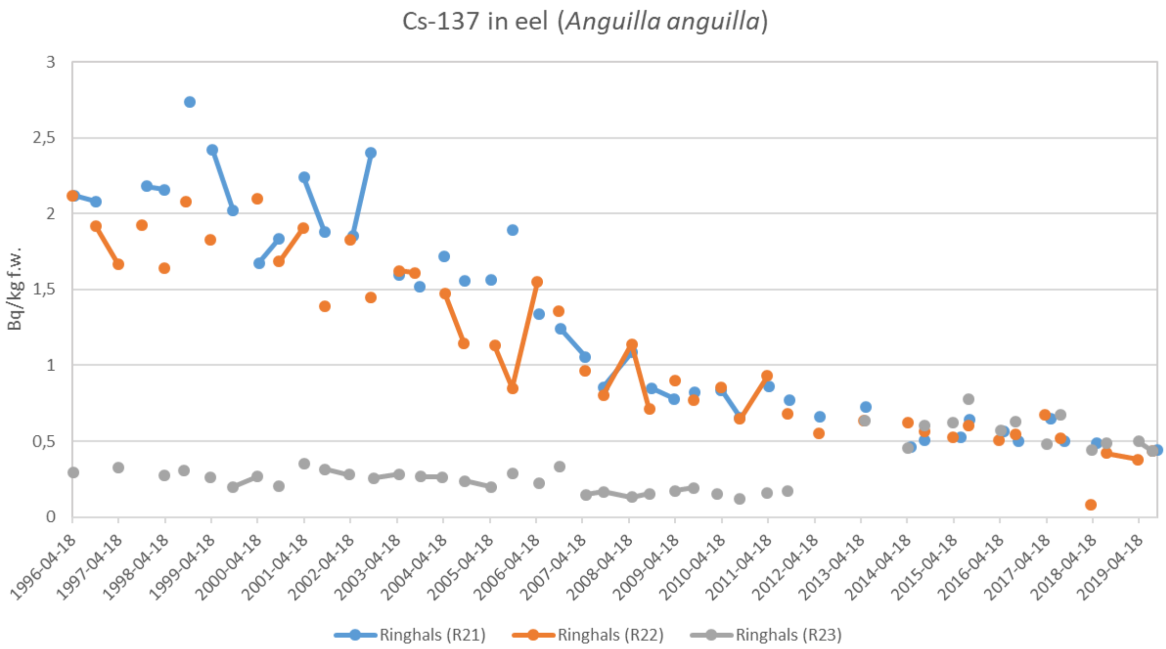

Figure 4.4 *Concentration of Cs-137 in eel (Anguilla anguilla) at the Swedish sampling stations in Bq /kg f.w.*

Seawater is sampled at two stations, R35 and SW7 (Figure 4.1), and the concentrations of Cs-137 and tritium (H-3) is reported. The levels remain stable over the time period examined.

The concentrations of Cs-137 in the environment are caused by several sources, in particular by fallout from the Chernobyl accident in 1986 and to a lesser extent from the atmospheric nuclear bomb tests and from discharges from nuclear reprocessing facilities in other parts of Europe. The concentrations of Co-60, Mn-54 and Co-58 are low and for Mn-54 and Co-58 mostly below the limit of detection.

4.1.1. Quality assurance – environmental monitoring

The SSM environmental monitoring program describes in detail sampling, sample preparation and measurement and is implemented in local instructions. Analyses are done at a special low-background laboratory at the site. Analysis aims for detection limits better than 1 Bq/kg for typical activation product. Instruments are calibrated against certified standards. Weekly checks are done on detector stability and energy calibration is checked in connection to every analysis. SSM annually carries out bilateral comparisons on several types of environmental samples with the Swedish nuclear site operators to ensure quality of measurement of site effluents and environmental samples, as well as regular proficiency test in various sample matrices from the environment.

4.1.2. Other relevant information

There is no other relevant information.

4.1.3. Data completeness and compliance

Data submitted have been complete in all aspects where the format is relevant.

4.2. Summary evaluation - Environmental Impact

The environmental monitoring is performed in a way that is relevant for judging long-term trends, for performing model verification, and for judging compliance with environmental goals. The data indicate low environmental concentrations of key nuclides and do not reveal increasing trends. Although there are no systems in place to assess impact on non-human biota, present knowledge indicates that the discharges from the Ringhals NPP cause no harm to the marine ecosystems.

The following Table 4.1 summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on Environmental Impact from Ringhals NPP.

Table 4.1 Summary Evaluation of Environmental Impact

Criteria	**Evaluation**
The BAT/BEP indicators	
• Downward trends in concentrations	Low and stable or declining concentrations
• Relevant environmental program	Yes
• Relevant quality assurance program	Yes
Data completeness	Yes
Causes for deviations from indicators	No deviations
Uncertainties	The largest uncertainty is related to the representation in the samples (variability)
Other information	None

5. Radiation doses to the public

5.1. Average annual effective dose to individuals in the critical group

According to the Swedish regulations (SSMFS 2008:23), the effective dose to an individual of the public from one year of releases of radioactive substances to air and water from all facilities located in the same geographically delimited area shall not exceed 0.1 mSv.

From 2019 a new methodology is used for estimating doses to the public. The new methodology is assessed and approved by the SSM. The major differences are that the methodology uses new and up-dated parameters and assumptions, is more site specific than earlier methods, the integration period in the environment is 100 years instead of 50 as before, and the concept of representative person from ICRP 101 is applied. This has resulted in somewhat higher calculated dose to the public as can be seen in figure 5.1. below.

The annual average effective doses to individuals of the public from discharges and emissions is below 0,1 mSv for the period 1974-2019 (Figure 5.1).

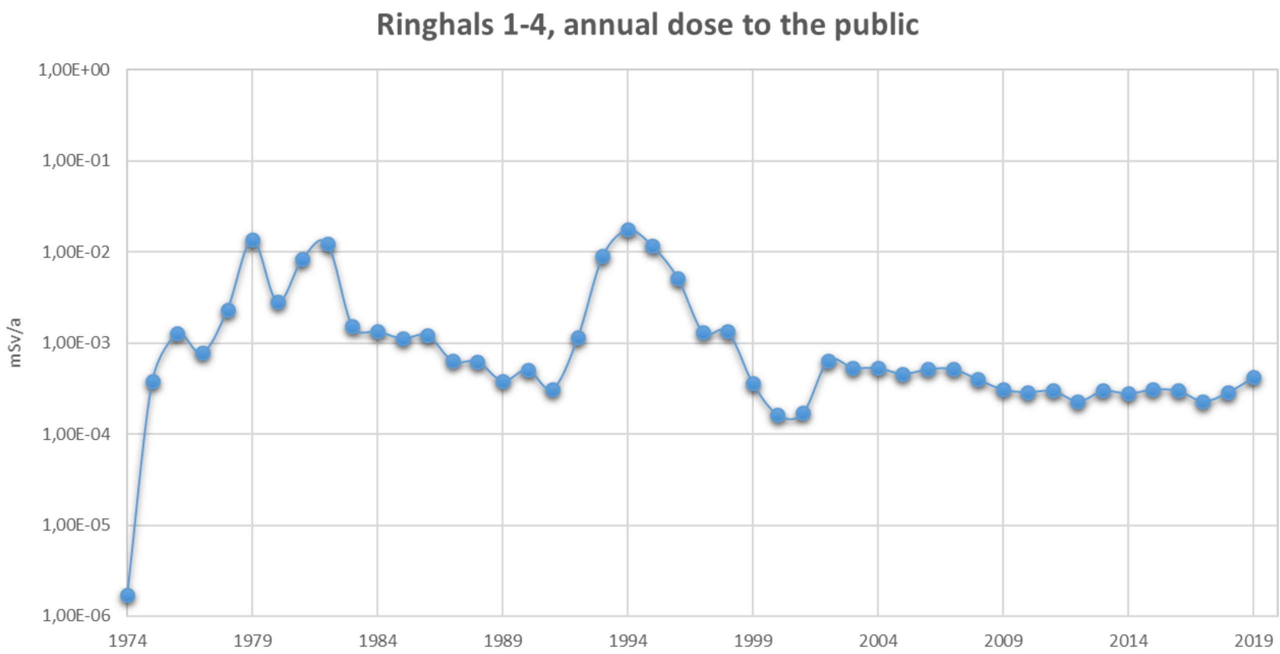

Figure 5.1 *Annual dose to the public from Ringhals NPP (mSv/a).*

5.2. Summary evaluation - Doses to the public.

The following Table 5.1 summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on Radiation Doses to the Public from Ringhals NPP.

The methods for estimating doses are relevant for judging exposure of the population and to comply with dose limits and constraints. Doses to the public are well below any dose limits or dose constraint and are stable or declining due to managerial and technical improvements made at the facility.

Table 5.1 *Summary Evaluation of Radiation Doses to the Public*

Criteria	Evaluation
The BAT/BEP indicators	
• Downward trend in radiation dose	Stable
• Relevant critical group/ representative person	Yes
• Reliable dose estimates	Yes
• Relevance of target dose	No target dose, but dose constraint for the site
• Relevant quality assurance systems	Yes
• Data completeness	Data are complete
• Causes for deviations from indicators	No deviations
• Uncertainties	No influence on the conclusions
Other information	None

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Our vision is a clean, healthy and biologically diverse North-East Atlantic Ocean, which is productive, used sustainably and resilient to climate change and ocean acidification.

Publication Number:797/2021