OSPAR COMMISSION

Protecting and conserving the North-East Atlantic and its resources

Swedish Implementation Report of PARCOM Recommendation 91/4 on radioactive discharges

Radioactive Substances Series

2018

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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This report has been prepared by Karin Aquilonius and Anki Hägg for Sweden as the lead country with the support of Dan Aronsson, Ringhals AB.

1. Summary

PARCOM Recommendation 91/4 concerns the use of best available technique (BAT) to minimise and, as appropriate, eliminate any pollution caused by radioactive discharges from all nuclear industries, including research reactors and reprocessing plants, into the marine environment.

This report concerns the implementation of BAT in the nuclear power plant at Ringhals, the only Swedish nuclear facility concerned, in accordance with PARCOM Recommendation 91/4.

According to Guidelines for the Submission of Information about, and the Assessment of, the Application of BAT in Nuclear Facilities (OSPAR agreement 2004-03) the Contracting parties shall present a statement on progress made in applying such technology every four years in accordance with the guidelines annexed to this recommendation.

As so far there have been six rounds of reporting according to the above mentioned recommendation. Sweden has reported compliance with PARCOM Recommendation 91/4 during all six implementation rounds. The first three reports from Sweden also included the Barsebäck nuclear power plant, which discharges in close proximity to the Convention waters.

The report provides an update of the use of BAT during 2012-2016.

2. Introduction

The PARCOM Recommendation 91/4 concerns application of best available technique (BAT) to ”respect the relevant recommendations of the competent international organisations an to apply the Best Available Technology (BAT) to minimise and, as appropriate, eliminate any pollution caused by radioactive discharges from all nuclear industries, including research reactors and reprocessing plants, into the marine environment. Contracting parties shall present a statement on progress made in applying such technology every four years in accordance with the guidelines annexed to this recommendation.”

The guidelines for reporting were revised after the first two rounds and used on a trial basis in the third implementation round [OSPAR reference number 1999:11]. Following an evaluation of the third round of implementation reports, RSC 2003 agreed to revise the Guidelines. The revision took into account the experience gained with the application of the guidelines in the third round of implementation reporting and also consider the guidelines in the wider context of the revised Joint Assessment and Monitoring Programme (JAMP). RSC 2004 agreed [RSC 04/13/1] on the proposed revised guidelines for the submission of information on assessment of the application of BAT in nuclear facilities in the context of PARCOM Recommendation 91/4 (OSPAR agreement 2004-03) should be used for the next implementation round.

At RSC 2016 [RSC 16/09/01] it was decided to review PARCOM Recommendation 91/4 and the reporting procedures (agreement 2004-03). This work i still in progress and will be discussed on RSC 2018. At RSC 2017 [RSC 17/07/01] it was decided to re-start the 7th reporting round with Sweden, the Netherlands and the United Kingdom reporting in time for RSC 2018. The report from Sweden follows the guidelines given in (OSPAR agreement 2004-03).

3. General information

3.1 The Radiation Safety Authority

The Swedish Radiation Safety Authority (SSM) is the authority under 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 practises. 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 combined with fines, as well as to issue new conditions for the operation of a facility.

3.2 Implementation of BAT/BEP in terms of the OSPAR Convention in Swedish legislation and regulations

According to the Guidelines, this section only considers legislation and regulations that are new or changed since the latest implementation round as described in the previous Swedish implementation reports.

The Swedish legislation and regulations concerning the implementation of BAT/BEP in the terms of the OSPAR Convention have not been changed since the 6th implementation report. However the Swedish Radiation Protection Act and its ordinance and relevant radiation safety regulations are being extensively revised but are not yet in force and will therefore not be presented in this report.

3.2.1 The Swedish Radiation Protection Act

There are no changes in the Act since the third implementation round of reporting related to what is considered as BAT and how BAT is being applied in Sweden.

The aim of the Radiation Protection Act [SFS 1988:220] is the protection of man and the environment against harmful effects of radiation. In the explanatory text to the Act [Governmental Bill 1987/88:88], it is clarified that 6 §, *inter alia*, refers to the requirement that radiation protection shall be in reasonable accordance with technical and methodological development, and shall be improved as technological and methodological development so permits (i.e. BAT shall be applied, although the term is not used *per se*).

The Radiation Protection Ordinance (1988:293) contains details pursuant to authorisation in the Radiation Protection Act. The Ordinance authorises the SSM to act as the central administrative authority in the area of radiation protection.

The SSM may issue regulations [SSM Code of Statutes, SSMFS], based on authorisation in the Radiation Protection Ordinance. The SSM is also responsible for the surveillance of the activities of the operator.

3.2.2 The Environmental Code

The Environmental Code [SFS 1998:808] is a comprehensive legislation covering a wide range of environmental issues, including provisions on environmental impact assessments, licensing procedures, etc. The Code entered into force 1st January 1999. The Code is applicable to activities generating ionizing radiation in the environment. Such activities are categorized as 'environmentally hazardous', together with numerous other activities [9 Chapter section 1]. The Code specifically identifies BAT as a means for achieving the goal of preventing, eliminating or reducing the impact on health and the environment of human activities [2 Chapter section 3].

3.2.3 Regulations issued by the SSM

There are no changes in regulations since the third implementation round of reporting related to what is considered as BAT and how BAT is being applied in Sweden.

On the basis of the authorisation granted in the Radiation Protection Ordinance, SSM has issued '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, which entered into force 1st January 2002, are

1 § …… applicable to the following nuclear facilities for which the Government has granted permission under section 5 of the Act (1984:3) on Nuclear Activities:
1. nuclear power reactor,
2. research or material testing reactor,
3. facility for fabrication of uranium pellets and nuclear fuel bundles,
4. facility for storage or other handling of spent nuclear fuel and
5. facility for storage, handling or final disposal of nuclear material or nuclear waste.

The regulations are applicable to all releases of radioactive substances from nuclear facilities that are directly related to the normal operation at each facility.

The regulations are not applicable
1. to shallow land burials of low-level nuclear waste under section 19 of the Ordinance (1984:14) on Nuclear Activities or
2. to the transport of nuclear material or nuclear waste outside the operational area of a facility or
3. to the dismantling of a nuclear facility or
4. after the closure of such a waste facility as that intended in the Swedish Radiation Protection Authority's Regulations (SSMFS 2008:21) on the Protection of Human Health and the Environment in connection with the Final Management of Spent Nuclear Fuel and Nuclear Waste.

The regulations identify BAT as a means for limitation of releases as specified below:

3 § The limitation of releases of radioactive substances from nuclear facilities shall be based on the optimisation of radiation protection and shall be achieved by using the best available technique. The optimisation of radiation protection shall include all facilities located within the same geographically delimited area.

The possibility that radiation doses to the personnel can increase when releases to the environment are limited shall be taken into account during the optimisation as shall the consequences of other waste management alternatives.

In the regulations, best available technique is defined as 'the most effective measure available to limit the release of radioactive substances and the harmful effects of the releases on human health and the environment, which does not entail unreasonable costs'.

BAT is applicable to all sources of radioactivity at a nuclear facility. In particular, nuclear power reactors are emphasised by the introduction of so called reference values and target values for the releases of radioactive substances. The reference value 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 values are operating experience and knowledge of the size of releases, in a historical perspective. Reference values can also comprise indicators of the efficiency of the effluent treatment systems. The reference values will be different for different reactors. It is important to point out that these values do not comprise limits or guidance levels, but can be considered to be a measure of the normal abatement capability. The values can consequently be changed, for example, when there is a change in release-limiting systems. Taking the BAT concept into consideration the facility shall also establish target values for each nuclear power reactor. The target value should show "the level to which the radioactive releases from nuclear power reactors can be reduced during a certain period of time". The difference between reference values and target values is that reference values describe the current situation whereas target values indicate what can be achieved.

3.3 Dose constraints/limits for nuclear facilities

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

According to the regulations [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 millisievert (mSv). The effective dose, which concerns the dose from external radiation and the committed effective dose from internal exposure, shall be integrated over a period of 50 years. When calculating the dose to individuals in the critical group, both children and adults shall be taken into consideration. Dose coefficients that are to be used for intake and inhalation are specified in European Council directive 2013/59/Euratom.

When the calculated dose is 0.01 mSv or more per calendar year, realistic calculations of radiation doses shall be conducted for the most affected area. The calculations shall be based on measured dispersion data and knowledge of the conditions within the most affected area for the period concerned.

3.4 Discharge limits

SSM has not defined any radionuclide specific discharge limits. Limitation of releases is being implemented through the restriction of dose to the critical group members. For each nuclear facility, e.g. each reactor at Ringhals, and for each radionuclide that may be released, specific release-to-dose factors have been calculated. The factors have been calculated for hypothetical critical groups, and take into consideration local dispersion conditions in air and in the environment, local settlements, local production of food-stuffs as well as moderately conservative assumptions on diet and contribution of locally produced food-stuff to the diet of the group. The latest revision of release-to-dose factors are based on more realistic assumptions than earlier and in line with the requirements in the EU BSS.

For nuclear power reactors, release-to-dose factors (mSv/Bq) have been calculated for 97 radionuclides that may be discharged to the marine environment and 159 radionuclides that may be emitted to air. The dose contributions from all monitored radionuclides released are summed, and this sum shall not exceed 0.1 mSv for a calendar year.

In principle, all released radionuclides should be monitored. In practice, however, there are a number of deviations. Since 2002, the emissions of C-14 and H-3 shall be monitored. Discharges shall be controlled through the measurement of representative samples for each release pathway. The analyses shall include nuclide-specific measurements of gamma and alpha-emitting radioactive substances as well as, where relevant, strontium-90 and tritium. Measurements of C-14 in discharges is not mandatory.

3.5 Monitoring programmes of environmental concentrations of radionuclides

The regulations [SSMFS 2008:23] include provisions on environmental monitoring.

20 § Environmental monitoring shall be conducted in the surrounding areas of nuclear facilities in accordance with programmes formulated by the Swedish Radiation Safety Authority. The programmes 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 programme 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 programmes vary depending on the facility and are divided in a terrestrial and an aquatic part. 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 programme involving spring and autumn sampling is conducted. Furthermore, certain samples are taken on a monthly and quarterly basis. In addition to the basic programme, extended sampling is also conducted every fourth year at the most of the facilities. The extended programme 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 programme, SSM performs inspections and takes random sub-samples for measurements at the SSM or at independent laboratories.

The environmental samples consist of local flora and fauna e.g. algae, fish, shellfish, mosses, game and sediment as well as local food products (grain, milk etc.). The types of samples for the marine environment in the vicinity of the Ringhals NPPs are specified in further detail in Tables 3.1. and 3.2. The compulsory nuclide library used in environmental monitoring is given in Table 3.3.

Table 3.1 *Overview of marine environmental sampling at Ringhals nuclear power plants*

Type of sample	Number of sampling stations	Period S= Spring, A= Autumn
Seawater	1	Quarterly
Sediment	2 1	Quarterly A
Algae		
Green algae, Cladophora sp.	(7)	A, substitute sample for fucus
Bladder wrack, Fucus vesiculosus	7	A
Diatomic algae	2	Monthly
Molluscs & Arthropods		
Sea mussel, Mytilus edulis	3	A
Lobster, Homarus gammarus	1	A
Crab, Cancer pagurus	1	A
Crab, Carcinus maenas	1	A
Fish		
Eel, Anguilla anguilla	3	SA
Cod, Gadus morrhua	1	A
Plaice, Platichtys flesus	(1)	SA, substitute for scorpion fish
Herring, Clupea harengus	1	A
Scorpion fish, Myoxocephalus scorpius	1	SA

Table 3.2 *Overview of extended programme, to be executed every fourth year*

Type of sampling	Number of additional sampling stations
Algae	
Green algae, Cladophora sp.	2
Bladder wrack, Fucus vesiculosus	9
Molluscs	
Littorina sp.	3
Sea mussel, Mytilus edulis	5
Sediment	13

Table 3.3 *Nuclide library used for gamma-spectrometric measurements of environmental samples*

Nuclide	Water, sedentary microalgae and sediment	Other samples
Be-7		•
Na-22	•	•
K-40		•
Cr-51	•	•
Mn-54	•	•
Fe-59	•	•
Co-57	•	•
Co-58	•	•
Co-60	•	•
Zn-65	•	•
As-76	•	
Zr-95	•	•
Nb-95	•	•
Nb-95m	•	•
Mo-99	•	
Ru-103	•	•
Ru-106	•	•
Ag-108m	•	
Ag-110m	•	
Sn-113	•	•
Sn-117m	•	•
Sb-122	•	
Sb-124	•	•
Sb-125	•	•
Te-129m		•
Te-132		•
I-131	•	•
Cs-134	•	•
Cs-136	•	•
Cs-137	•	•
Ba-140	•	•
La-140	•	
Ce-141	•	•
Ce-144	•	•
Eu-152	•	•
Eu-154	•	•
Eu-155	•	•
Gd-153	•	•
Hf-181		•

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

The regulations (SSMFS 2008:23) further stipulate that:

21 § At the request of the Swedish Radiation Protection Authority, a separate environmental monitoring shall be conducted and the environmental consequences to the most affected area assessed for all events resulting in an increased release of radioactive substances to the environment.

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. Also:

22 § Continuous measurements of gamma radiation shall be conducted in the environment around nuclear power reactors, research reactors or material testing reactors. 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).

23 § 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.

3.6 Environmental norms and standards (other than dose standards for humans)

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.

3.7 National authority responsible for supervision of discharges

The Swedish Radiation Safety Authority, SSM (see also Section 3.2.1) is the national authority responsible for supervision including the regulation of the releases of radioactive substances from nuclear facilities

3.8 Nature of inspection and surveillance programmes

SSM performs inspections at the nuclear facilities in which systems for collecting data on releases and environmental radioactivity are assessed. These inspections include all aspects of data collection (online

measurements, filter systems, waste water sampling), measurement (laboratories and equipment), quality assurance and reporting.

The SSM undertakes a number of checks of the measurements performed by the operator, concerning gamma emitters, alpha emitters, tritium and strontium-90. Pooled and stabilised annual samples from each monitored waste water stream shall be sent to the SSM within three months after the end of the discharge year. In addition a number of randomly chosen monthly samples of waste water are analysed by SSM. The annual samples are measured concerning gamma emitters and tritium by the SSM and the results are compared with the data submitted by the operators. These measurements are conducted at the SSM laboratories. Control measurements of Sr-90 and alpha-emitting radionuclides are performed on a case by case basis at independent external laboratories.

Aerosol filters shall be sent to the SSM for control measurements on request. Normally, this exercise is performed once a year and the filters are subjected to gamma-spectrometric analyses.

Environmental measurements are checked by the SSM. A total number of up to 50 samples, obtained as sub-samples of the material analysed by the operator or the laboratory contracted by the operator, is analysed annually. Measurements are normally performed gamma-spectrometrically. Samples may also be used for alpha-spectrometric analysis as well as for measurements of strontium-90.

SSM conducts regular inter-comparisons, where the operators analyse samples (liquid samples, filter samples or environmental samples of unknown activity) prepared by SSM. The SSM itself participates in international inter-comparisons, e.g. those organised by the IAEA and WHO.

Monitoring data shall, according to the SSM Regulations on Archives at Nuclear Facilities [SSMFS 2008:38], be preserved and shall, after decommissioning of the plants, be transferred to national archives. Stabilised pooled annual samples of waste water shall be stored at the facilities for at least 10 years and similar regulations apply to aerosol filters and environmental samples. Iodine filter samples shall be stored for three months.

4. SITE-SPECIFIC INFORMATION – RINGHALS NUCLEAR POWER PLANT

4.1 Site characteristics

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

4.1.2 Type of facility
A nuclear power plant with one boiling water reactor, BWR (ASEA Atom, now Westinghouse Electric Sweden AB) and three pressurised water reactors, PWR (Westinghouse). Auxiliary facilities for waste treatment, maintenance, etc., and a shallow land repository for low-level radioactive waste resulting from the operation of the plant.

4.1.3 Start of operations
The start of operations for the four reactor units are given in Table 4.1.

Table 4.1 *Start of operations (criticality and commercial operation) for the Ringhals reactor units*

Unit	Type	Criticality, year	Commercial operation, year
1	BWR	1973	1976
2	PWR	1974	1975
3	PWR	1980	1981
4	PWR	1982	1983

4.1.4 Location
The Ringhals nuclear power plant is located at the Swedish West Coast, approximately 50 km S Göteborg and 15 km N Varberg.

4.1.5 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.

4.1.6 Production
The installed electrical effect (MW_e) and the annual electrical output (GWa) for the years 2008–2016 are given in Table 4.2.

Table 4.2 *Installed electrical effect and net electrical output, Ringhals units 1 - 4*

Unit	1	2	3	4
Gross Power, MWe	860	917	1050[1]	960
Net Power, MWe	830	875	1000[2]	915
Year	**Net GWa**			
2008	0,520	0,656	0,868	0,837
2009	0,150	0,315	0,925	0,853
2010	0,410	0,639	0,866	0,825
2011	0,682	0,197	0,816	0,468
2012	0,628	0,411	0,947	0,799
2013	0,696	0,719	0,788	0,845
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

4.1.7 Other relevant information
There is no other relevant information.

4.2 Discharges

4.2.1 Plan for the implementation of BAT
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 (see table 4.3).

Table 4.3 *Thermal installed effect*

	Installed (MW)	Increase (MW)	After Uprate (MW)
R1	2500	50	2550
R2	2660	50	2710
R3	2783	376	3159
R4	2783	517	3300

The license was issued in 2006. The Swedish Radiation Safety Authority (SSM) is following the implementation of the agreed action plan during routine inspections and surveillance programs.

4.2.2 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 are segregated according to contents of activity and

[1] Power up-rated from 960/915 MW in January 2007

[2] Power up-rated from 960/915 MW in January 2007

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 dose to the critical group 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 4.4–4.7.

In 2002, a R&D pilot plant for cross-flow filtration in combination with different absorbers and resins was taken into operation in Ringhals unit 2 (Table 4.5). During normal operations it handles the full volume of waste water. However, it cannot handle the large volumes of water that are discharged in a shut-down transient situation. Improvements on filtration are done in Ringhals 3 and Ringhals 4. New selective filters are now in use.

At Ringhals 1 a large storage tank has been installed in 2008 to make re-use of process water possible. The evaporator equipment at Ringhals 1 has been refurbished and improved. It has been put into operation 2011 and undergone gradual improvements since than which results in significantly decreased releases to water.

Major changes in liquid waste management have taken place in Ringhals 1 (1998), Ringhals 2 (2000), Ringhals 3 (1999) and Ringhals 4 (1999), in order to separate waste streams for improved treatments (Tables 4.4–4.7). For the three PWR:s, some highly contaminated waters are transferred to Ringhals 1 waste treatment plant.

At Ringhals 3 a system for delay of gases released from an auto-ventilation system of the charging pumps has been finally implemented in 2013.

At Ringhals 4 a system for reduction of Argon in make-up water has been tested. This minimizes the production of activated Ar-41.

4.2.3 Systems to reduce, prevent and eliminate emissions

In 1998 (Table 4.4) recombiners were installed in Ringhals unit 1. This led to increased delay times and a significant reduction of releases of noble gases. The full performance of the system operation was achieved during the year of 2000. Improvements implemented during the time-period are marked as green in table 4.4–4.7).

4.2.4 Efficiency of abatement systems

The efficiencies of the abatement systems in place in the four Ringhals reactors are summarised in Tables 4.4–4.7.

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 4.4 *Ringhals 1 - 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	Decontamination 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			Reduces the volume of water that has to be processed at peak and will indirectly improve decontamination	
Evaporator	2011		10		Investigation on waste treatment of evaporator concentrate. Refurbishment of and improvements 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 4.5 *Ringhals 2 - 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**	**Decontamination 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 decayed		
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.
Programme 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 ultrasonics.	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 4.6 *Ringhals 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	Decontamination 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 decayed		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 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	
Programme 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.	

Table 4.7 *Ringhals 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	Decontamination 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 has decayed		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
Programme 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.
Programme 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 1 waste treatment plant.	1999		>10		

4.2.5 Annual liquid discharges

Absolute discharges

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, as indicated in Tables 1-4 in APPENDIX 1 and Figures 4.1 – 4.4.

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 (2008 – 2016), one fuel leakage was detected. The leackage occurred at Ringhals 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).

In 2009 SSM revised the reporting requirements in order to be fully in line with the EU recommendations 2004/2/Euratom and the ISO standard 11929-7:2005. As a result of this, more radionuclides are reported and included in the total-alpha and total-beta values reported to OSPAR. For total-beta, the overall picture with downward trends is not affected. For total-alpha the influence of the change in reporting methods are more visible and has to be taken into account when evaluating trends in discharge.

Figure 4.1. *Discharges of H-3, total beta excl. H-3 and total alpha from Ringhals Unit 1 (Bq/year)*

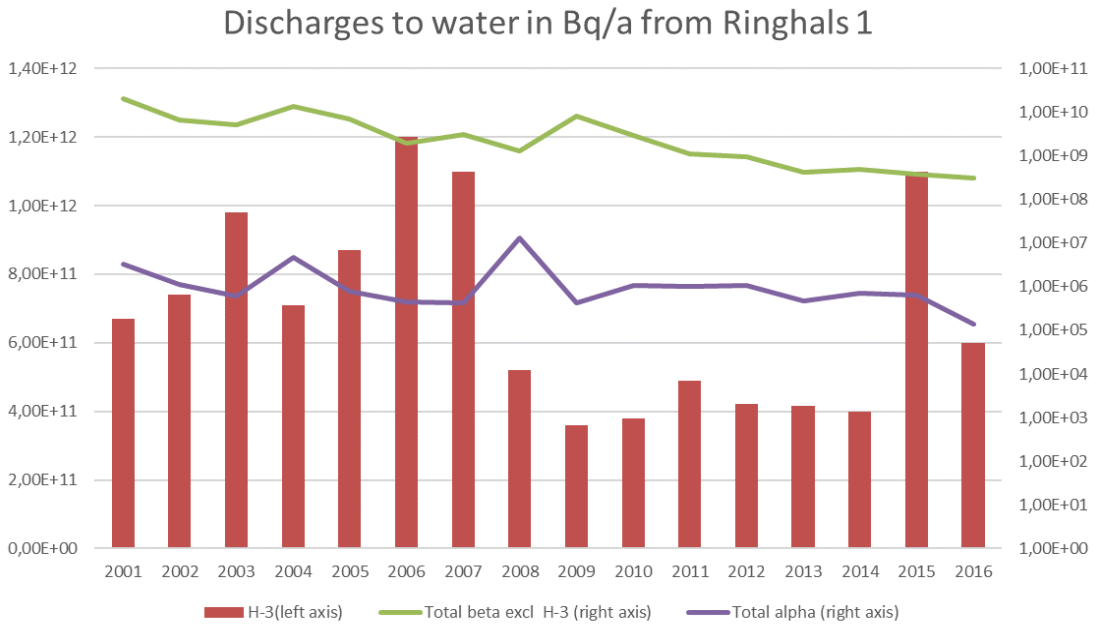


Figure 4.2A *Discharges of total beta excl. H-3 and total alpha from Ringhals Unit 2 (Bq/year)*

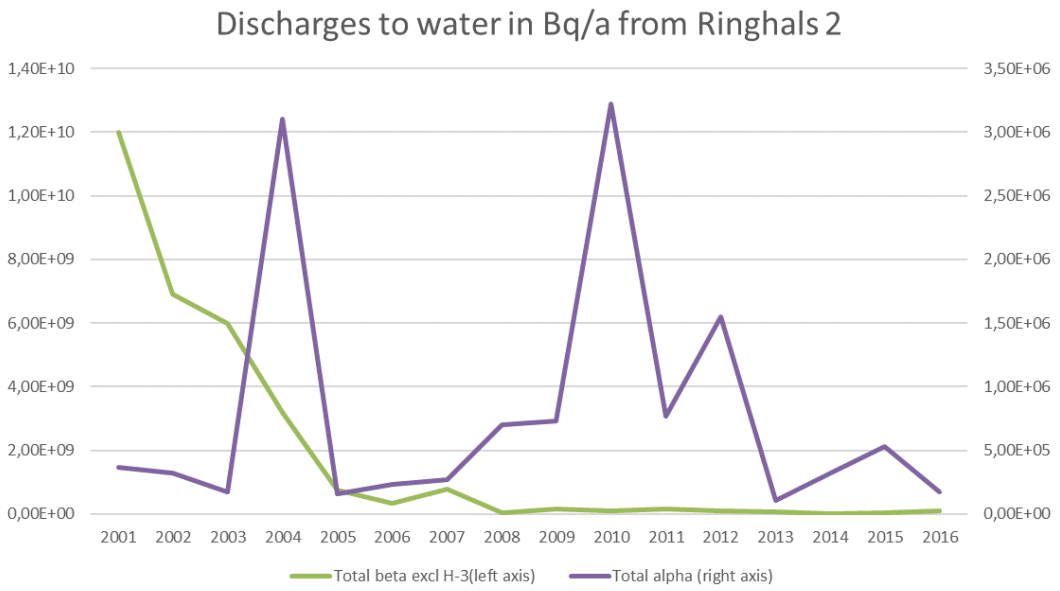


Figure 4.2B *Discharges of H-3 from Ringhals Unit 2 (Bq/year)*

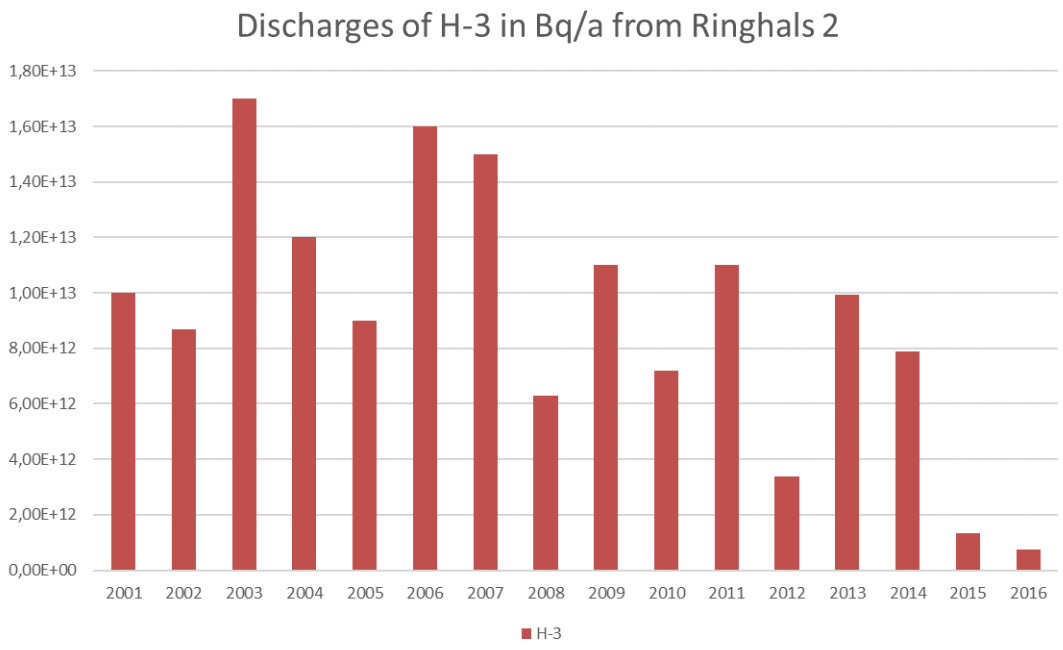


Figure 4.3A *Discharges of total beta excl. H-3 and total alpha from Ringhals Unit 3 (Bq/year)*

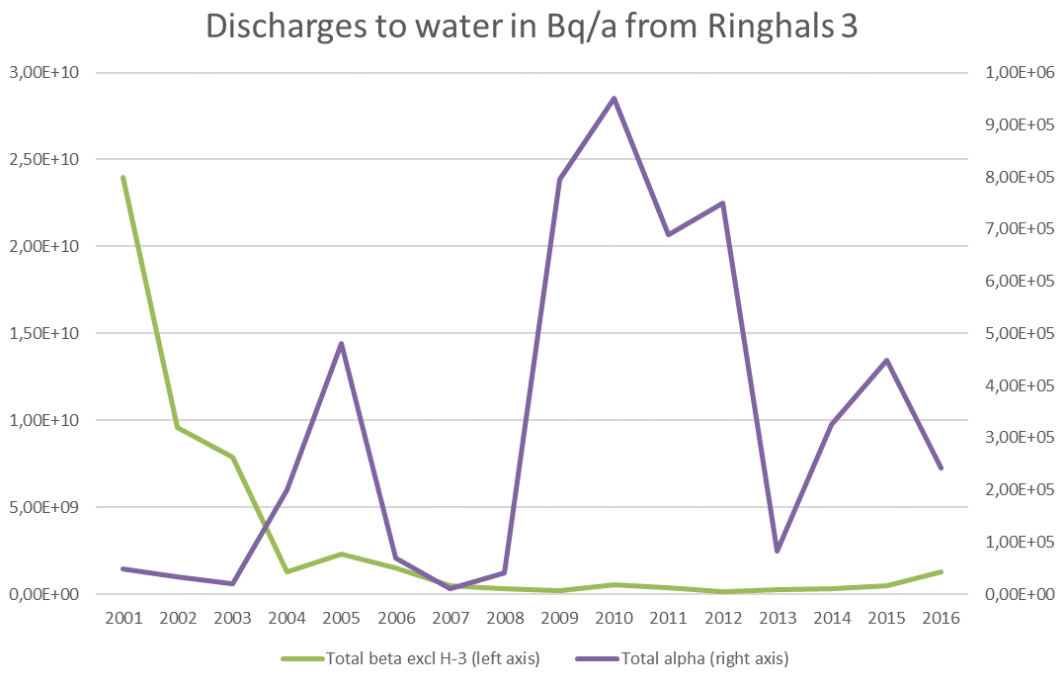


Figure 4.3B *Discharges of H-3 from Ringhals Unit 3 (Bq/year)*

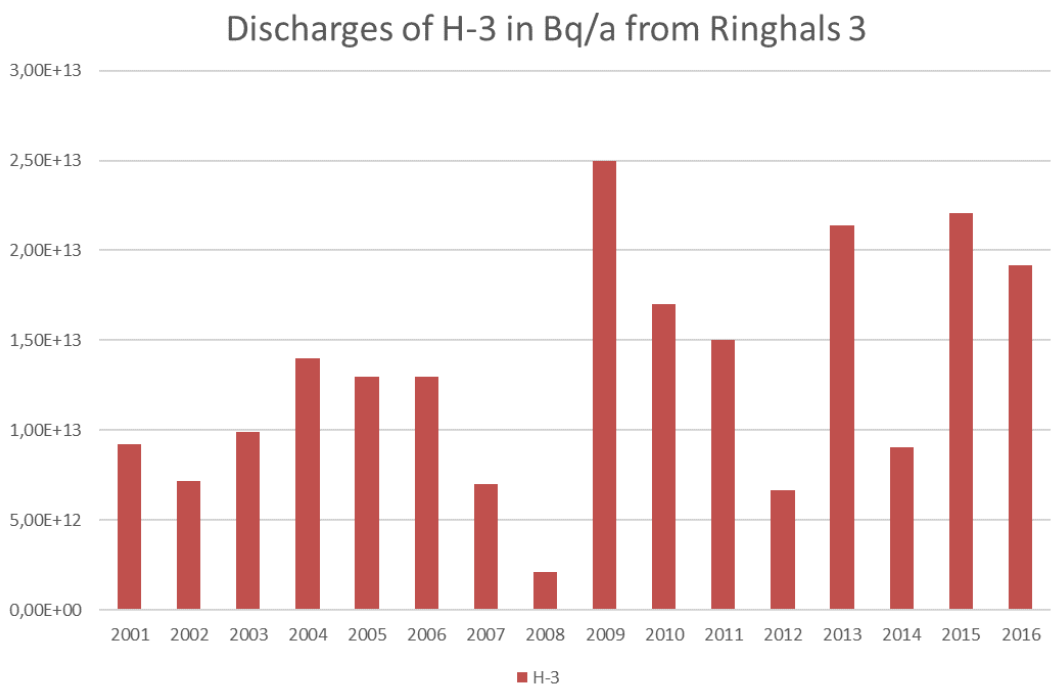


Figure 4.4A *Discharges of total beta excl. H-3 and total alpha from Ringhals Unit 4 (Bq/year)*

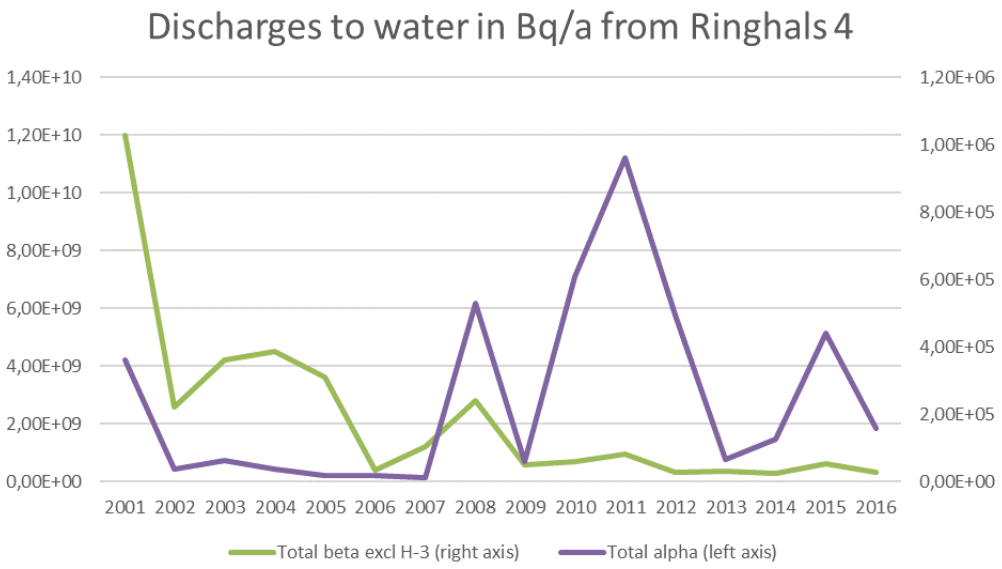
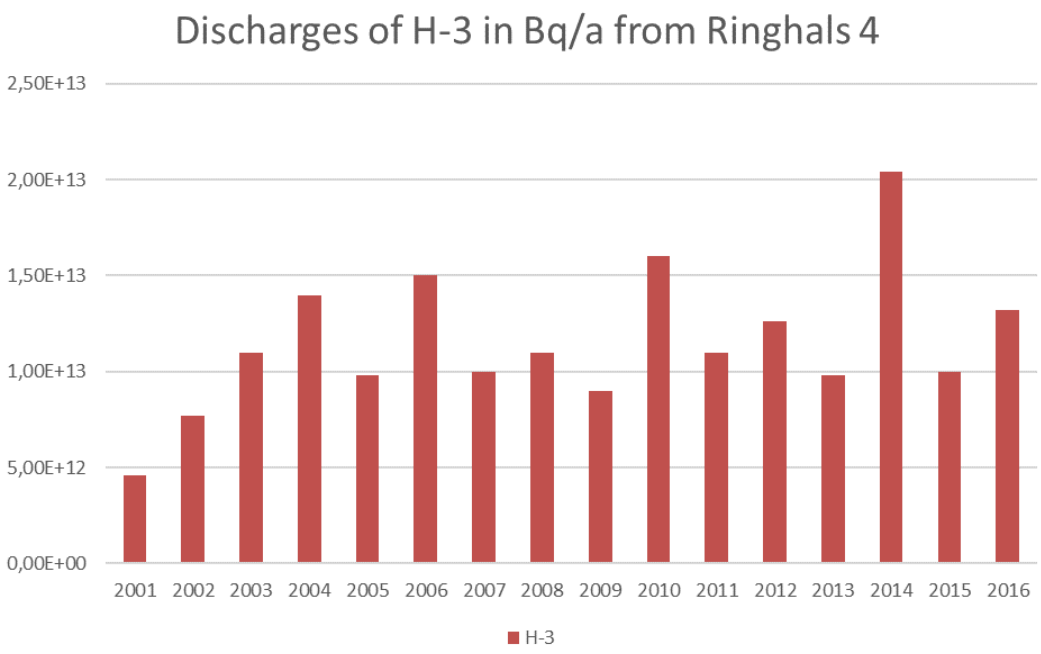


Figure 4.4B *Discharges of H-3 in from Ringhals Unit 4 (Bq/year)*



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 value for all reactors of the same type based on data published by UNSCEAR. In recent PARCOM 91/4 implementation rounds and as an indication of BAT, ranges have been constructed from the global mean value corresponding to a factor of 10 around the mean value. Using UNSCEAR 2000 data, such ranges are given in Table 4.7. These ranges are still valid for comparision even if the UNSCEAR report published in 2000 only covers data until 1997.

Table 4.7 *Normalised ranges for annual discharges of beta emitters from BWRs and PWRs, based on UNSCEAR 2000*

Reactor type	H-3 (TBq/GWa)	Beta emitters (H-3 excluded) (GBq/GWa)
BWR	0.29-2.88	3.6-35.7
PWR	5.91-59.1	2.6-25.9

According to the UNSCEAR 2008 report covering data until 2002, the average values for PWRs for the time-period 1998-2002 are: 2,1 TBq/GWa for Tritium and 0,22 TBq/GWa for Carbon-14. For BWRs the corresponding values are: 1,6 TBq/GWa for Tritium and 0,53 TBq/GWa for Carbon-14.

The average values for the period 2002-2016 from the three PWRs at Ringhals are 0,6 TBq/GWa for Tritium and 0,2 TBq/GWa for Carbon-14. For the BWR at Ringhals the values for Tritium is 0,2 TBq/GWa and for Carbon-14 0,5 TBq/GWa.

The normalised discharge data for the Ringhals Units 1-4 are shown in Table 5 in APPENDiX 1 and in Figures below. Note that Ringhals 2 did not produce any electricity during the 2015.

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 “above range” may indicate that BAT is not applied for a specific source, whereas values “within range” or “below range” indicate that BAT may have been applied.

All values for Units 2-3 have been in-range during the period covered by this report. For 2009 the normalised total beta discharges from R1 were out of range. This was due to a very long outage period and low net energy production during 2009.

Figure 4.5a *Normalised discharges from Ringhals Unit 1 for total beta exclusive H-3 (GBq/GWa) including ranges according to UNSCEAR 2000.*

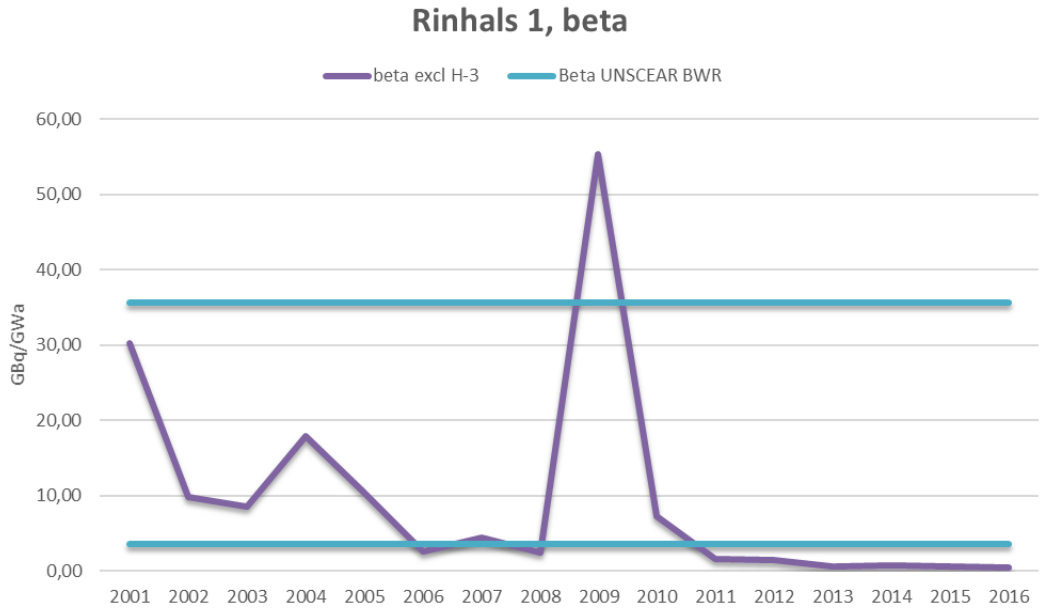


Figure 4.5b *Normalised discharges from Ringhals 1 for H-3 (TBq/GWa), including ranges according to UNSCEAR 2000.*

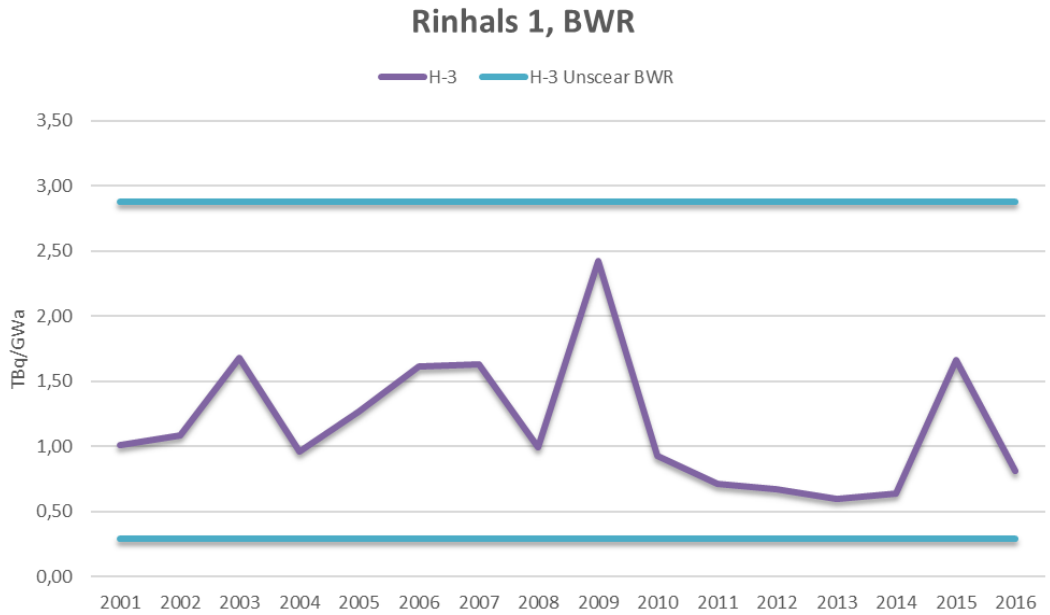


Figure 4.5c *Normalised discharges from Ringhals Unit 2-4 for total beta exclusive H-3 (GBq/GWa), including ranges according to UNSCEAR 2000*

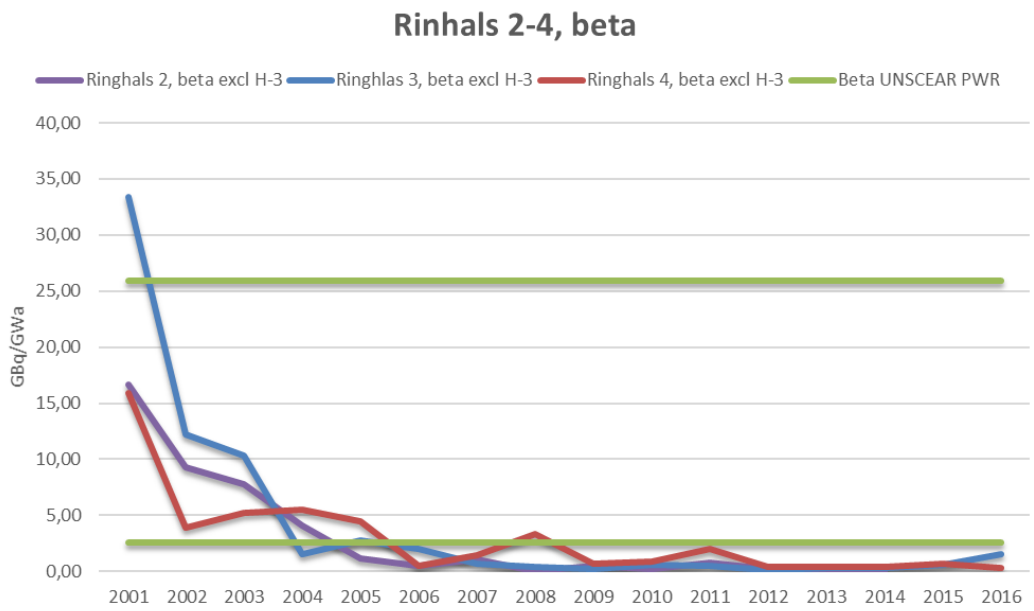
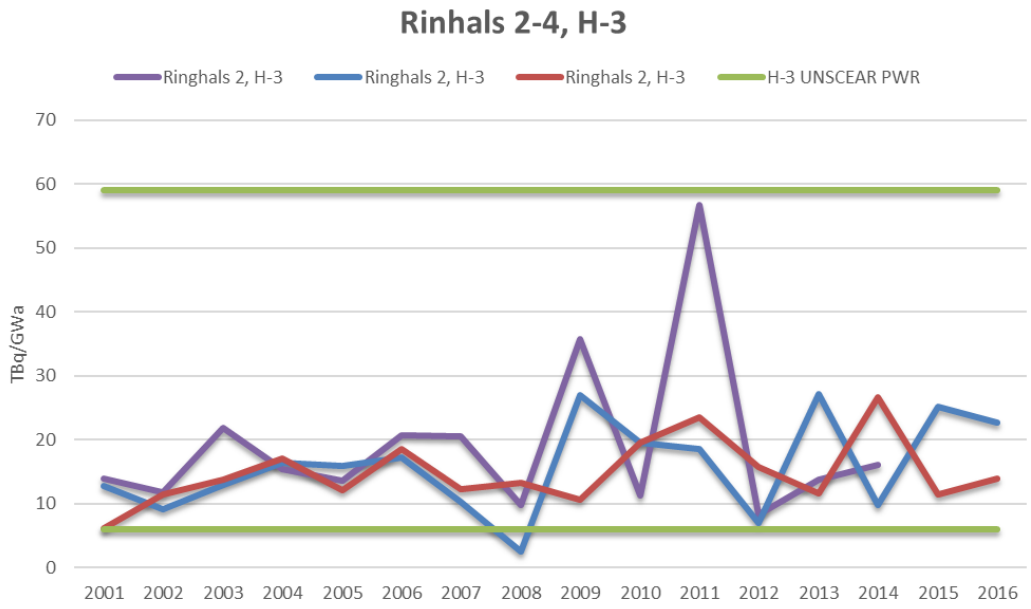


Figure 4.5d *Normalised discharges from Ringhals 2-4 for H-3 (TBq/GWa), including ranges according to UNSCEAR 2000.*



Absolute discharges

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, as indicated in Tables in Appendix 1 and Figures 4.5.

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

In 2009 SSM revised the reporting requirements in order to be fully in line with the EU recommendations 2004/2/Euratom and the ISO standard 11929-7:2005. As a result more radionuclides are reported and

included in the total-alpha and total-beta values reported to OSPAR. For total-beta, the overall picture with downward trends is not affected. For total-alpha the influence of the change in reporting methods are more visible and has to be taken into account when evaluating trends in discharges.

4.2.7 Quality assurance

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.

4.2.8 Site-specific target discharge

For nuclear power reactors site-specific target discharge levels are used. 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 nuclear power station, the reference and target values for discharges are shown in table 4.8

Table 4.8 Target values for discharges from Ringhals Units 1-4, and the monitored discharges for 2007 -2016

Unit	Radionuclide	2007	2008	2009	2010	2011	Target Value 2011	2012	2013	2014	2015	2016	Target Value 2016
R1	Co-58	3,2E+08	3,1E+08	7,2E+08	5,4E+08	1,2E+08	1,6E+08	1,44E+08	4,80E+07	4,80E+07	4,80E+07	1,80E+07	1,60E+08
	Co-60	1,5E+09	6,6E+08	6,8E+08	1,0E+09	2,7E+08	3,5E+08	3,85E+08	2,10E+08	1,75E+08	1,40E+08	8,40E+07	3,50E+08
	Cs-137	3,0E+08	2,4E+08	2,2E+08	2,9E+08	3,0E+07	6,2E+07	5,58E+07	2,48E+07	3,10E+07	8,68E+07	6,50E+07	6,20E+07
R2	Co-58	2,1E+07	1,2E+07	7,7E+06	5,9E+06	1,2E+07	2,6E+08	2,60E+06	0,00E+00	2,60E+06	0,00E+00	0,00E+00	1,00E+08
	Co-60	2,3E+07	1,6E+07	2,8E+07	3,1E+07	3,3E+07	1,4E+08	2,24E+07	8,40E+06	1,40E+06	5,60E+06	6,90E+06	5,00E+07
	Cs-137	2,1E+07	3,5E+06	5,8E+06	7,1E+06	3,2E+06	2,0E+07	3,20E+06	1,80E+06	8,00E+05	1,00E+06	1,70E+06	1,00E+07
	Sb-124	4,5E+08	2,8E+07	5,8E+06	7,9E+06	3,0E+06	1,0E+08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,40E+04	5,00E+07
R3	Co-58	7,1E+07	9,0E+07	4,1E+07	3,7E+07	3,8E+07	4,9E+08	1,96E+07	7,84E+07	9,31E+07	9,80E+07	5,20E+07	2,40E+08
	Co-60	1,2E+07	7,1E+07	7,5E+07	4,9E+07	3,5E+07	1,5E+08	1,50E+08	1,50E+08	1,50E+08	1,50E+08	1,50E+08	3,00E+07
	Cs-137	2,1E+06	1,6E+06	6,8E+05	1,4E+06	7,E+05	5,0E+06	7,60E+06	7,60E+06	7,60E+06	7,60E+06	7,60E+06	3,50E+06
R4	Co-58	9,2E+08	1,1E+09	4,3E+08	6,0E+08	6,5E+08	3,8E+09	3,80E+09	3,80E+09	3,80E+09	3,80E+09	3,80E+09	5,00E+08
	Co-60	4,4E+07	7,5E+07	3,8E+07	2,9E+07	3,2E+07	1,2E+08	1,20E+08	1,20E+08	1,20E+08	1,20E+08	1,20E+08	3,00E+07
	Cs-137	1,0E+06	4,1E+06	7,4E+05	4,7E+05	1,0E+05	5,0E+06	7,60E+06	7,60E+06	7,60E+06	7,60E+06	7,60E+06	3,50E+06

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.

Reference and targetvalues are also shown figure 4.6 below.

Figure 4.6a *Discharge of Co-58 from Ringhals 1, target level value and reference level*

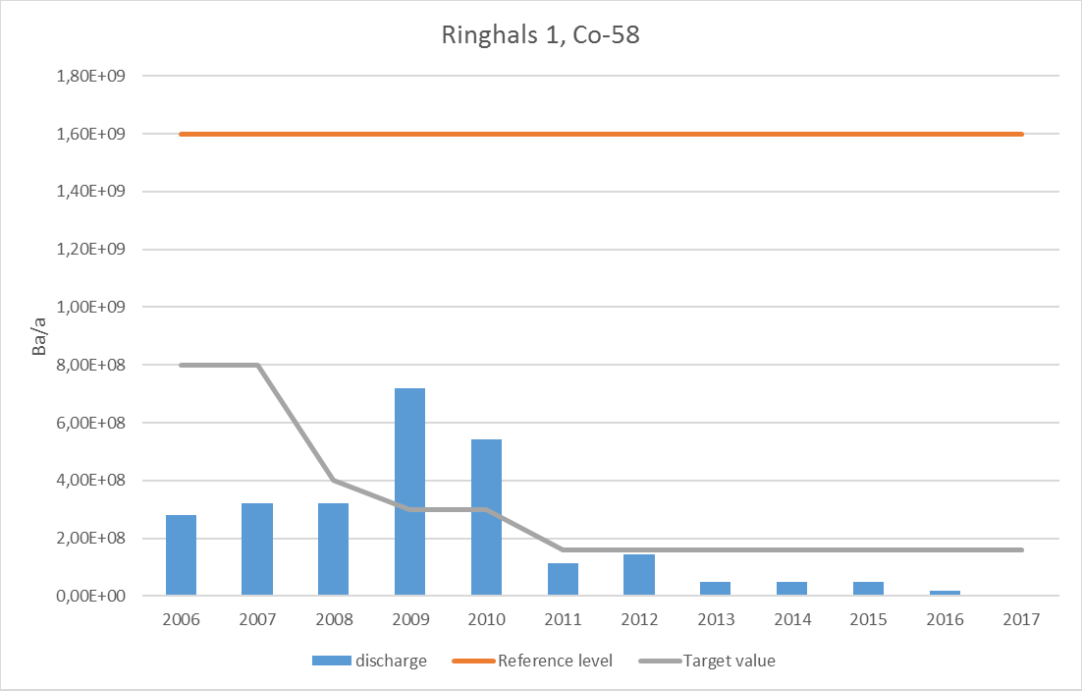


Figure 4.6b *Discharge of Co-58 from Ringhals 2, target level value and reference level*

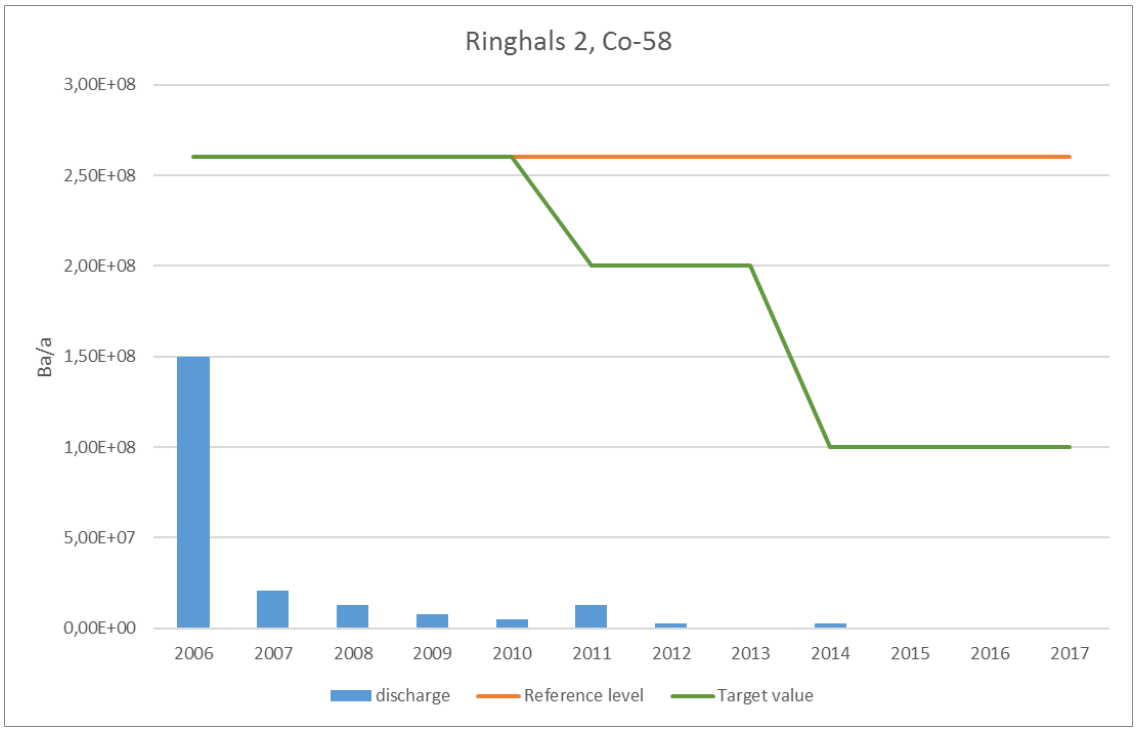


Figure 4.6c *Discharge of Co-58 from Ringhals 3, target level value and reference level.*

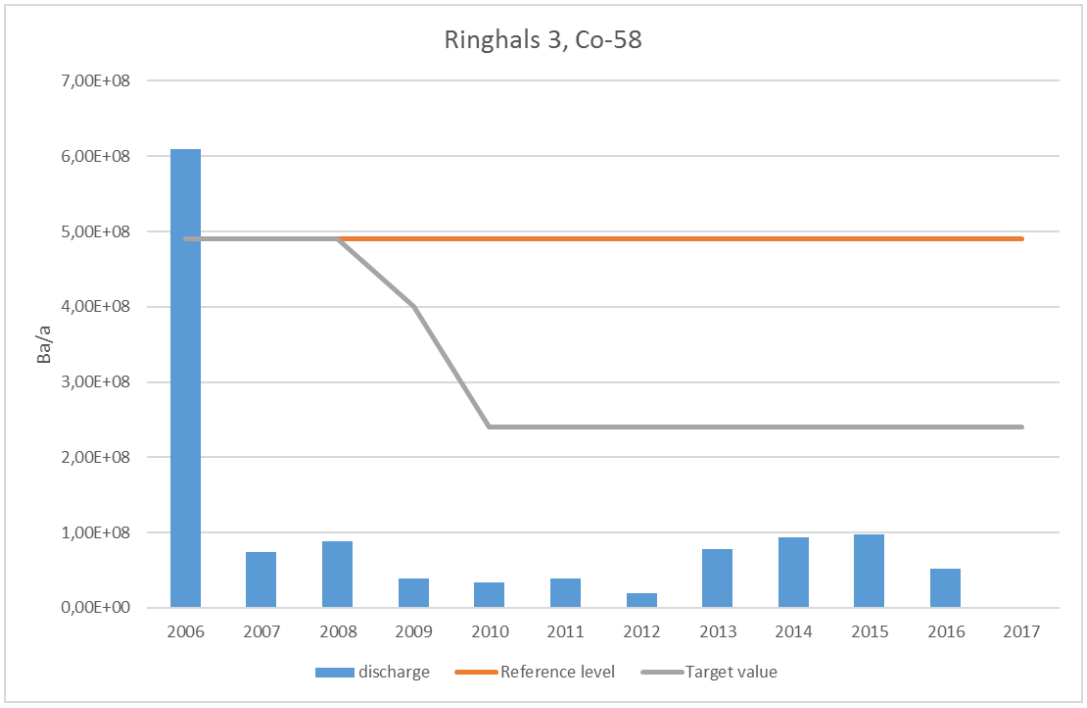


Figure 4.6d *Discharge of Co-58 from Ringhals 4, target level value and reference level*

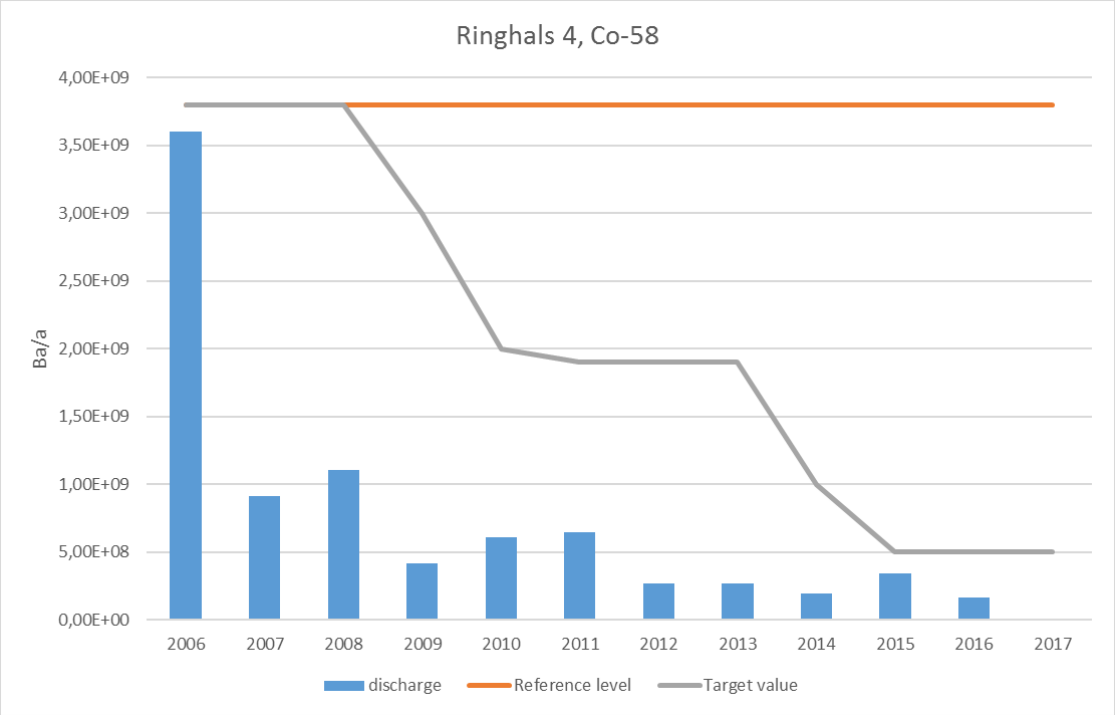


Figure 4.6e *Discharges of Co-60 from Ringhals 1, target level value and reference level*

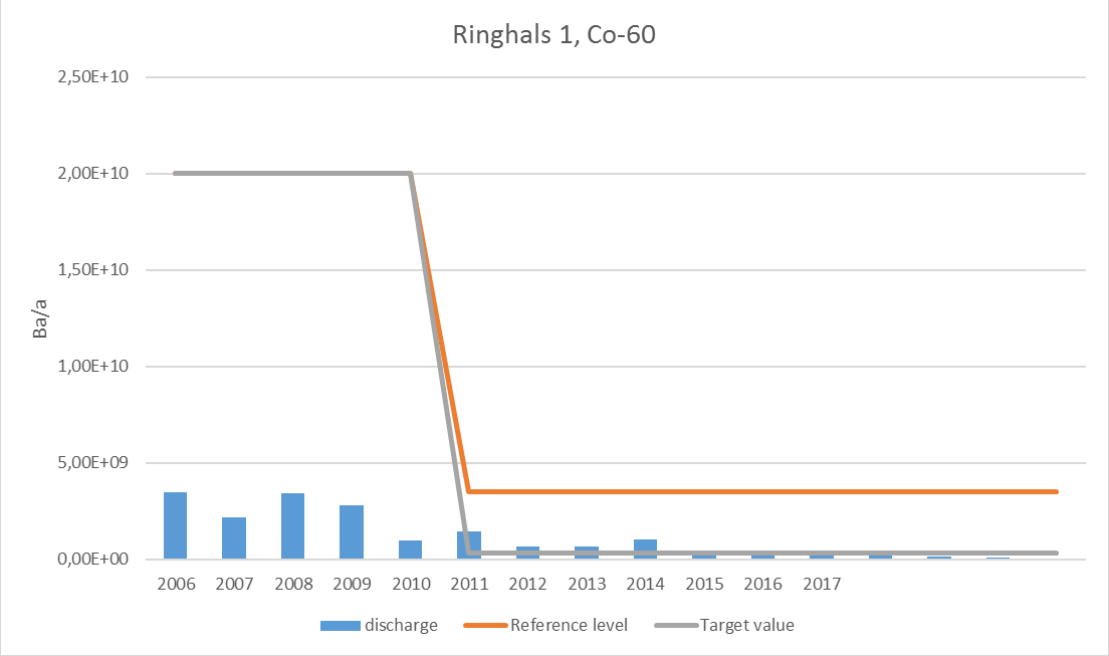


Figure 4.6f *Discharges of of Co-60 from Ringhals 2, target level value and reference level*

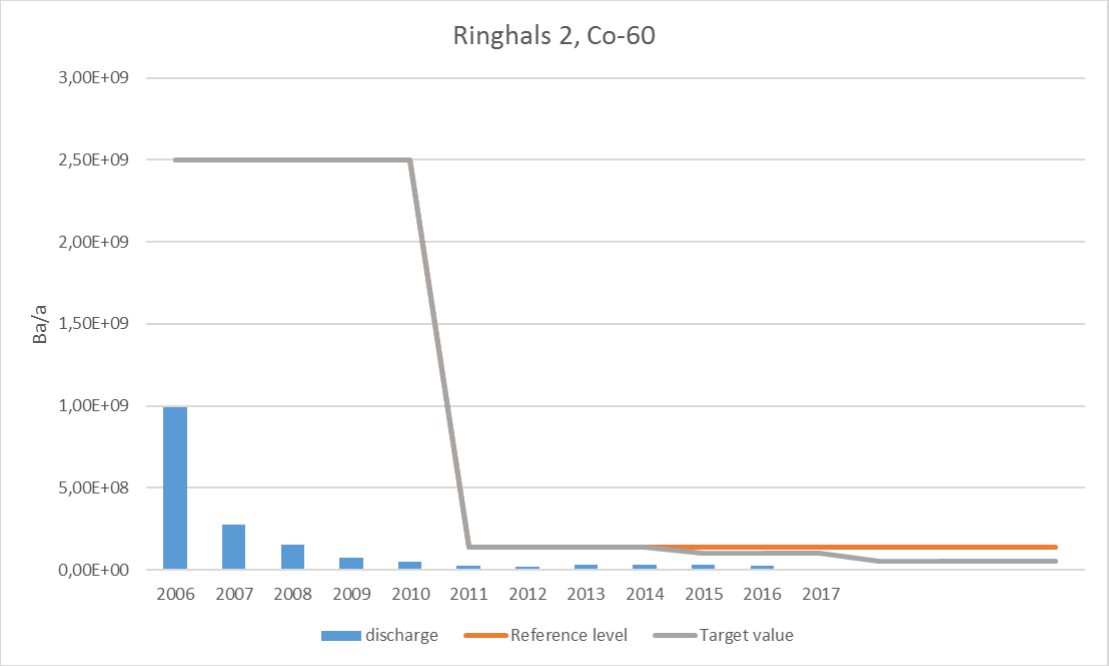


Figure 4.6g *Discharges of of Co-60 from Ringhals 3, target level value and reference level*

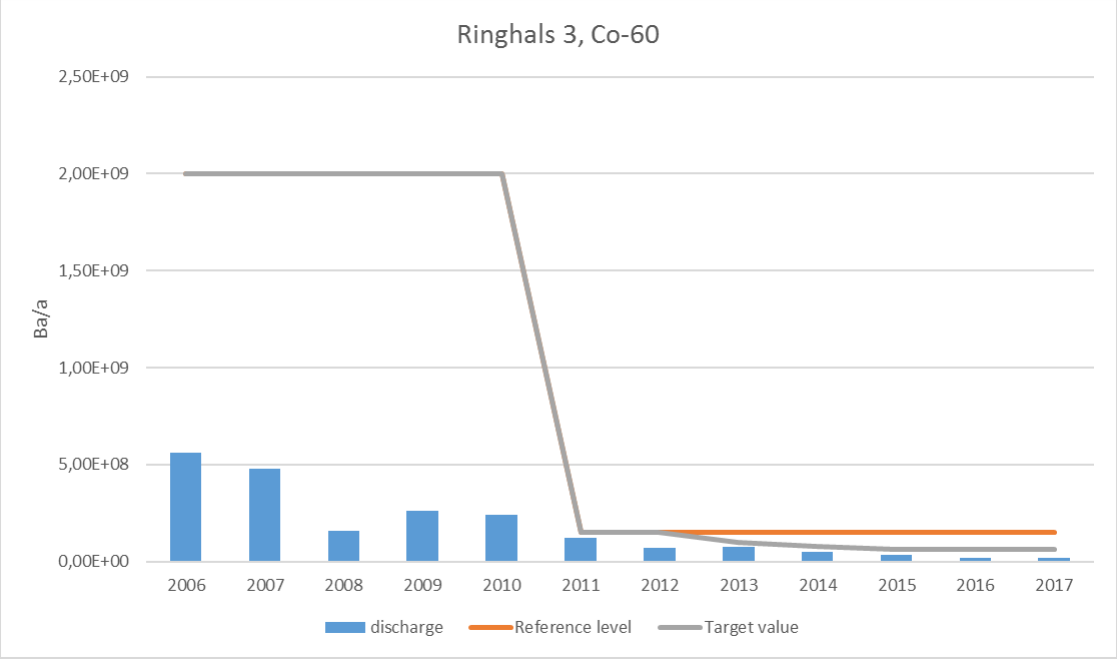


Figure 4.6h *Discharges of of Co-60 from Ringhals 4, target level value and reference level*

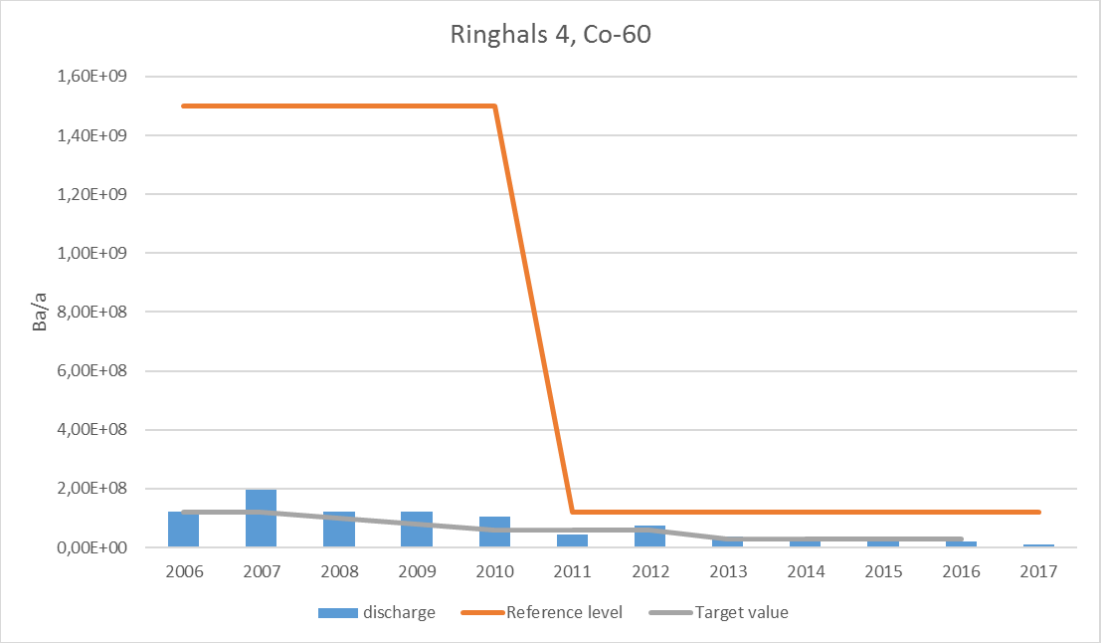


Figure 4.6i. *Discharges of Cs-137 from Ringhals, target level value and reference level*

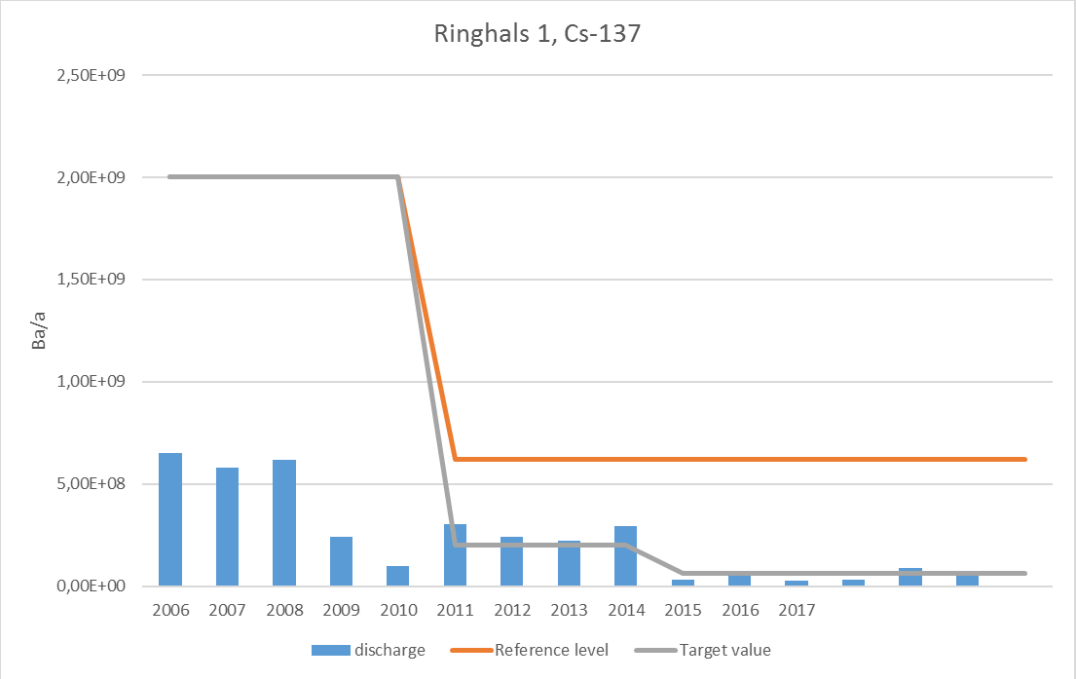


Figure *4.6j*.*Discharges of Cs-137 from Ringhals, target level value and reference level*

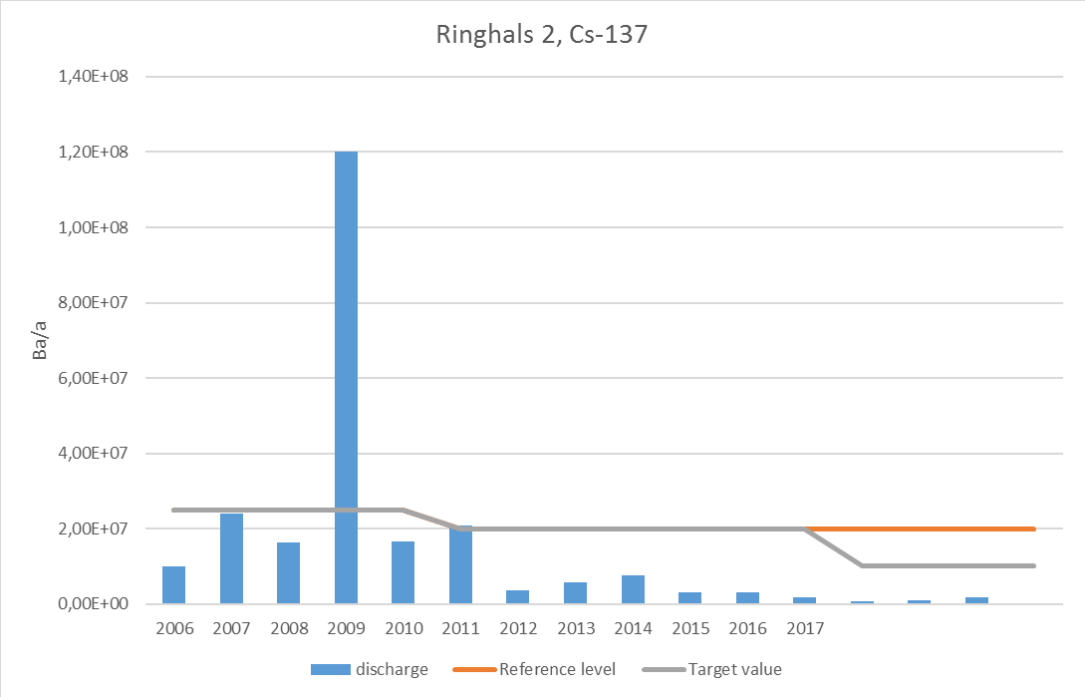


Figure *4.6k*.*Discharges of Cs-137 from Ringhals 3, target level value and reference level*

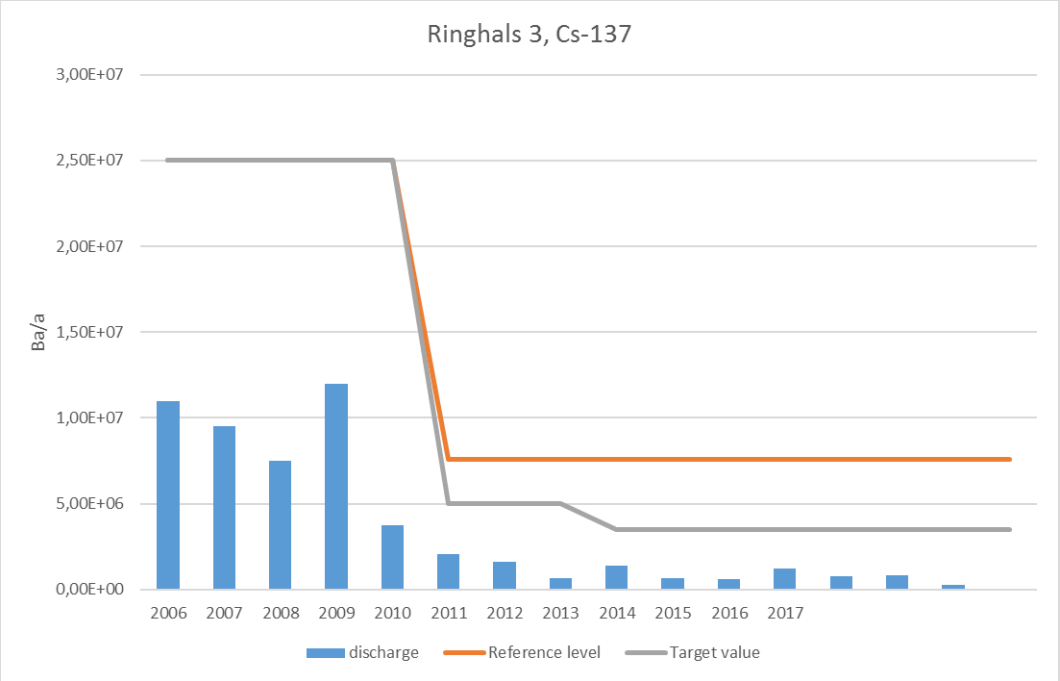
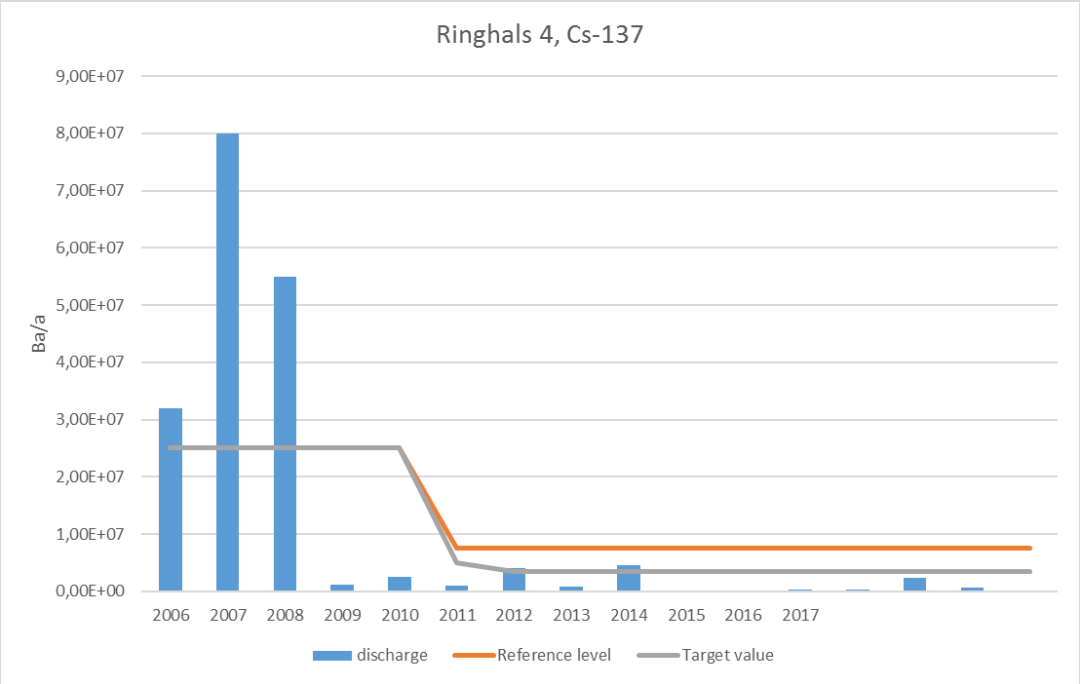


Figure *4.6l*.*Discharges of of Cs-137 from Ringhals 4, target level value and reference level*



4.2.9 Other relevant information

There is no other relevant information.

4.2.10 Explanations for lack of data or failure to meet BAT/BEP indicators, ongoing and planned activities

Activities

The main dose contribution to the critical group from the emissions and discharges from the Ringhals site has for many years originated from the emission of noble gases from unit 1, the BWR. Therefore, the operator has focussed on efforts to reduce the environmental impact by installing a recombinator in the delay system for noble gases. In order to further improve the delay of noble gases, the operator also has reduced the leakage of air into the turbine system. The dose contribution from the water discharges has been lower than the dose contribution from the emissions of noble gases so therefore a lower priority has been given to the reduction of the discharges. However, in parallel to reduction of emissions, the operator has also implemented modified procedures to reduce the discharges to water. In Unit 1 a project with the aim to identify each single contributing liquid waste stream has been performed.

There have been some problems with the evaporator at unit 1 but it is planned to be taken into permanent operation during 2013. At Ringhals 3 the collection and delay of the dominating stream of noble gas emissions have been improved during 2010 and 2011. At Ringhals 4 the membrane-filtration in the feed water system was permanently installed and taken into operation in 2008–2009. Also at Ringhals 4 the pH and red-ox operational control system have been optimised.

Data completeness and compliance

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

4.2.11 Summary Evaluation

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

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	Mainly 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	See text above
Uncertainties	No influence on the conclusions

Other information	None

4.3 Environmental impact

4.3.1 Concentrations of radionuclides of concern in environmental samples

The environmental monitoring programme is described in section 2.4. Below are examples of radionuclide measurements in sediment (fig. 4.7) and bladder wrack (fig. 4.8) is presented, and in tables in APPENDiX 1. The sediment samples have been taken at stations close to the discharge points, station 3 for sediment, and for station 3, 7, 13 and 25 for the bladder wrack samples. Results below detection limit is not shown in the diagram.

Figure 4.7 *Co-60, Cs-137, Co-58, Mn-54 and Nb-95 in sediment (Bq kg^{-1} dry wt) located at station 3*

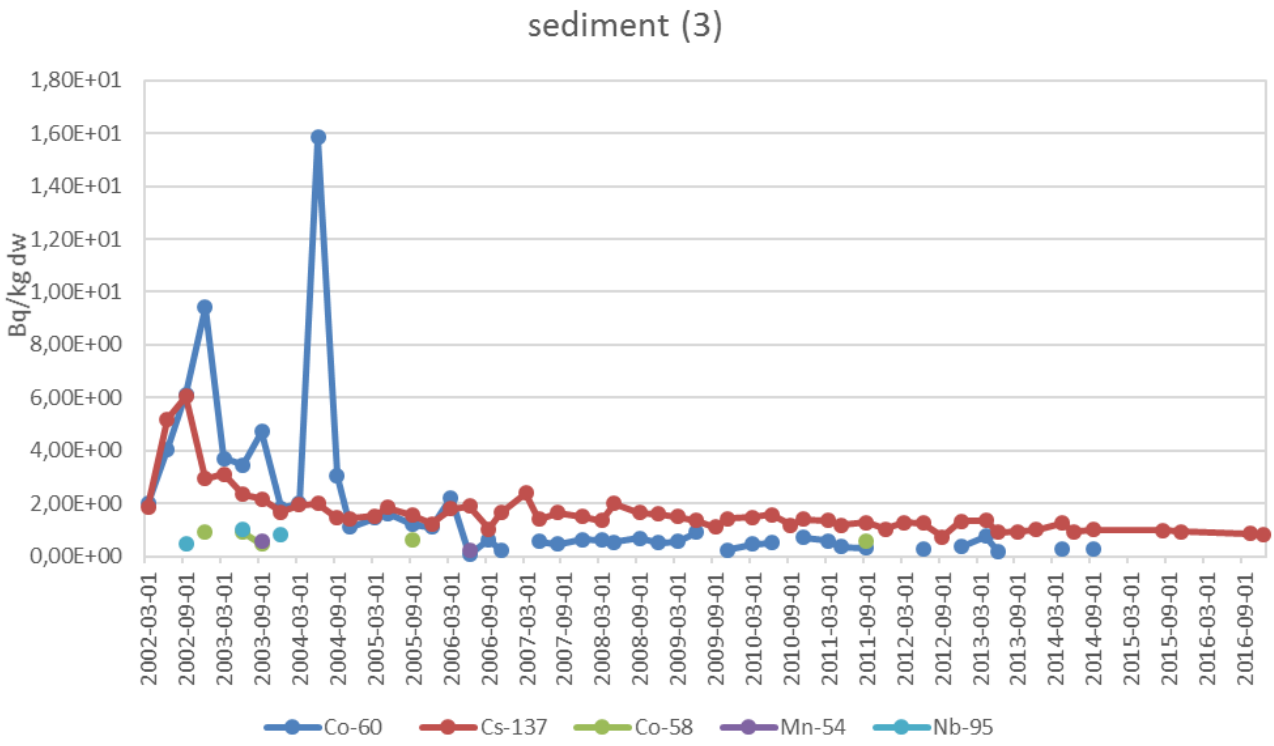
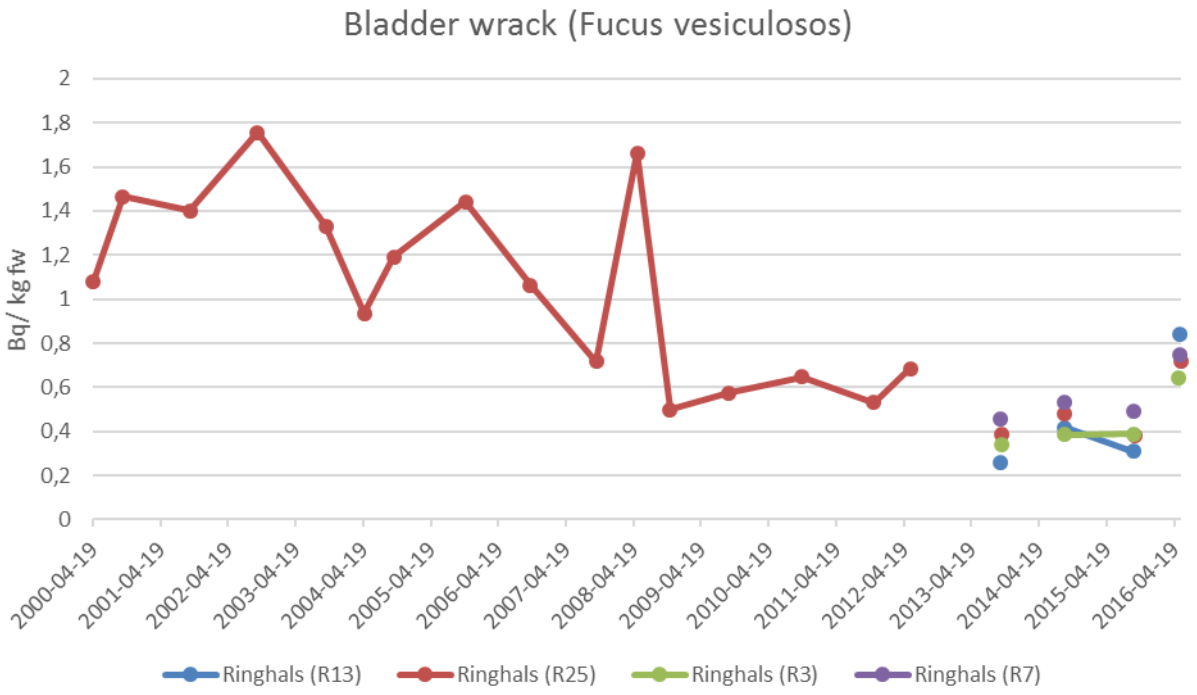


Figure 4.8 *Cs-137 in bladder wrack (Fucus vesiculosus) in (Bq kg^{-1} fresh wt) in 4 sample stations in subdivision 12.*



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. The values for concentrations in sediments are given in dry weight, and there are no detectable trends using ordinary trend detections methods.
The concentrations of Cs-137 in fish are given in wet weight and there is a decline trend.

4.3.2 Environmental monitoring programme, frequency of sampling, organisms and or other types of environmental samples considered
The environmental monitoring programme is described in section 3.5. In particular, the sample types collected and the frequency of collections are given in tables 3.1 and 3.2. The programme covers biotic and abiotic parts in the aquatic and terrestrial environments.

4.3.3 Systems for quality assurance of environmental monitoring
The SSM environmental monitoring programme 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. Annual checks are done through round-robin exercises engaging other plants and laboratories. SSM also check the environmental analyses through randomly selected sub samples which are being analysed at independent laboratories.

4.3.4 Other relevant information
There is no other relevant information.

4.3.5 Explanation of lack of data or failure to meet BAT/BEP indicators, ongoing and planned activities

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

4.3.6 Summary Evaluation

The following Table 4.9 summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on Environmental Impact from Ringhals four reactor units.

Table 4.9 **Summary Evaluation of Environmental Impact**

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

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 nuclear power plant cause no harm to the marine ecosystems.

4.4 Radiation doses to the public

4.4.1 Average annual effective dose to individuals in the critical group

According to the Swedish regulations (SSMFS 2008:23), the effective dose to an individual 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 millisievert (mSv). The effective dose, which includes the dose from external irradiation and the committed effective dose from internal irradiation, shall be integrated over a period of 50 years. When calculating the dose to individuals in the critical group, both children and adults shall be taken into consideration. Dose coefficients that are to be used for intake and inhalation are specified in Appendix III in European Council directive 96/29/Euratom.

The annual average effective doses to individuals of the critical group from discharges and emissions for the period 2002–2007 are given in Figure 4.10 and Table 4.10.

Figure 4.10 *Annual effective dose (microSv) to members of the critical group around Ringhals.*

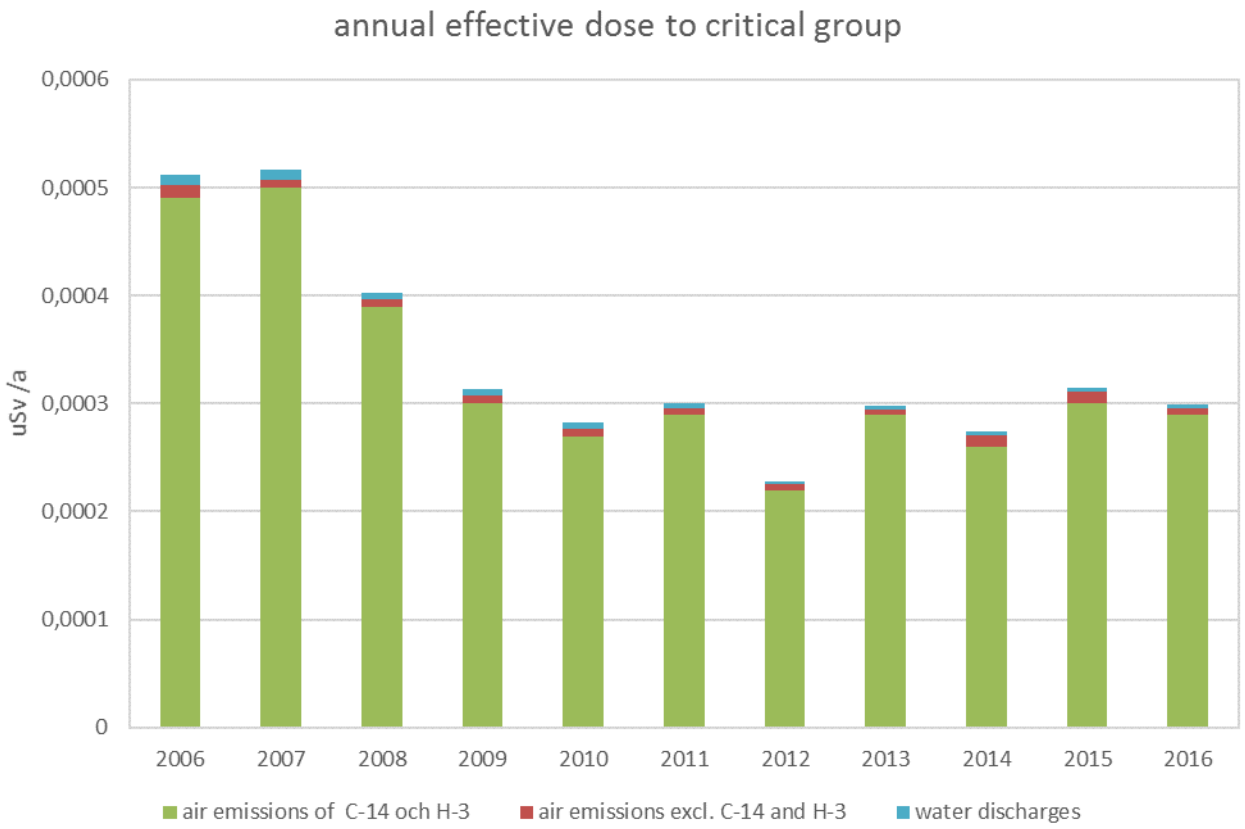


Table 4.10 *Annual effective dose to members of the critical group resulting from emissions and discharges from the Ringhals nuclear power plant (microSv/year)*

	air emissions of C-14 and H-3	**air emissions excl. C-14 and H-3**	**Water discharges**
2006	4,90E-04	1,20E-05	9,60E-06
2007	5,00E-04	7,60E-06	9,00E-06
2008	3,90E-04	6,80E-06	6,30E-06
2009	3,00E-04	7,10E-06	6,10E-06
2010	2,70E-04	6,20E-06	6,80E-06
2011	2,90E-04	6,10E-06	4,00E-06
2012	2,20E-04	5,00E-06	3,30E-06
2013	2,90E-04	5,00E-06	3,30E-06
2014	2,60E-04	1,10E-05	2,90E-06
2015	3,00E-04	1,10E-05	3,10E-06
2016	2,90E-04	5,36E-06	3,64E-06

The largest contribution to the dose is caused by emissions of C-14. The dose contribution from emissions have for many years been larger than the dose from discharges, but at the end of the reporting period the two dose contributions are about the same (C-14 not included).

4.4.2 The definition of critical groups

According to the definition in the Swedish regulations (SSMFS 2008:23), the critical group is a group comprising individuals whose exposure to a source is reasonably uniform and representative of that of the individuals in the population who are the more highly exposed to that source. The group includes six age groups according to European Council directive 96/29/Euratom. The group is hypothetical but realistic, taking average habits and exposure situations into account. The critical group for a specific year is that age group that received the highest dose as a result of that year's releases.

4.4.3 Information of exposure pathways

The radioecological and dose models were revised in 2002. This work included an evaluation of the exposure pathways. The exposure pathways found to be of importance were:

- inhalation
- external irradiation from radioactive substances in the air and on the ground
- consumption of meat, milk, cereals, roots, fruits, grown berries, vegetables and fish. For all sites, except Barsebäck, consumption of game, mushrooms and wild berries were also exposure pathways to be taken into account
- for Ringhals, also consumption of shell-fish is included
- drinking water is only included as a pathway for Forsmark and Studsvik.

All exposure pathways included in the calculations are treated separately. Release-to-dose factors have been calculated for more than 150 radionuclides.

The revision of the model also included updating of the data used in the calculations, investigating which data are dependent on age of the exposed individual, a more detailed description of the environment around the plant and a new model for uptake of C-14 in plants.

New radioecological and dose models are developed by the licence holders and are presently under review at the SSM, but the models from 2002 are still in use.

4.4.4 Basis for methodology to estimate doses

The model[3] used for calculating dispersion and migration of radioactive substances in the environment and for calculating the radiation doses was revised as a consequence of the regulations entering into force in 2002. The basic compartment model has been tested in international model validation studies.

4.4.5 Site specific factors for significant nuclides

For each radionuclide a site-specific release-to-dose factor is calculated reflecting the conditions representative for the site, see section 3.3 for more information.

4.4.6 Site-specific target annual effective dose

There is no site-specific target annual effective dose. The same constraint 0.1 mSv/year is valid for all nuclear sites irrespective of the number of sources within the site.

4.4.7 Systems for quality assurance of processes involved in dose estimates

When calculating the release-to-dose factors for the emissions and discharges, most parameters involved in the calculations have been entered as statistical distributions rather than deterministic values. A large number of calculations have been performed, using stochastic combinations of the parameter values. The release-to-dose factor used is the mean of the distribution. In addition, a standard deviation is also

[3] A model developed by Studsvik Eco & Safety

obtained for the dose factor. The main advantage of using this method is that virtually all data available for a parameter may be used in the calculation.

4.4.8 Any relevant information not covered by the requirements specified above
There is no other relevant information.

4.4.9 Explanations for lack of data or failure to meet BAT/BEP indicators, ongoing and planned activities
Data submitted have been complete in all aspects where the format is relevant.

4.4.10 Summary Evaluation
The following Table 4.11 summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on Radiation Doses to the Public from Ringhals four reactor units.

The methods for estimating doses are relevant for judging exposure of the population and to comply with dose limits and constraints. Doses are decreasing due to managerial and technical improvements made at the facility.

Table 4.11 *Summary Evaluation of Radiation Doses to the Public*

Criteria	Evaluation
The BAT/BEP indicators	
• Downward trend in radiation dose	Stable
• Relevant critical group	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	
Other information	None

4.5 Summary – BAT

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

APPENDIX 1

Table 1. *Discharges in Bq/year from Ringhals Unit 1, 2008-2016*

Nuclide	2008	2009	2010	2011	2012	2013	2014	2015	2016
H-3	5,20E+11	3,60E+11	3,80E+11	4,90E+11	4,23E+11	4,16E+11	4,00E+11	1,10E+12	5,99E+11
Cr-51		1,30E+08	7,80E+08	3,80E+07	7,15E+07	4,64E+07	1,03E+08	1,82E+07	2,19E+07
Mn-54		1,60E+08	2,00E+08	5,40E+07	1,27E+08	5,65E+07	7,00E+07	4,18E+07	3,19E+07
N-13									
Fe-59		1,10E+06		4,90E+06	1,05E+07	1,48E+06	9,89E+05		2,74E+06
Co-57		1,40E+06	1,90E+05	9,40E+04	6,42E+05	2,70E+05	1,25E+05		2,84E+05
Co-58	3,10E+08	7,20E+08	5,40E+08	1,20E+08	1,48E+08	5,53E+07	4,05E+07	4,15E+07	1,79E+07
Co-60	6,60E+08	6,80E+09	1,00E+09	2,70E+08	3,85E+08	1,96E+08	1,77E+08	1,47E+08	8,37E+07
Ni-63				5,70E+08	4,78E+07	1,28E+06	5,61E+06	2,50E+05	2,07E+07
Zn-65	8,70E+05	2,20E+06		2,80E+06	1,91E+06		3,13E+06	6,00E+05	1,80E+06
Zr-95		2,20E+07	1,90E+07	1,50E+06	3,05E+06	2,44E+05			
Nb-95		4,30E+07	3,30E+07	6,50E+06	1,11E+07	2,54E+06	1,04E+06	3,51E+05	4,28E+05
Zr/Nb-95	8,70E+05								
Ag-110m	4,50E+07	4,10E+07	2,00E+07	2,10E+07	4,06E+07	2,59E+07	4,76E+06	8,08E+06	6,67E+06
Sb-122									
Sb-124		2,40E+07	4,10E+07	4,90E+06	2,83E+07	2,75E+06	1,29E+07	1,08E+07	9,29E+05
Sb-125	1,70E+05	4,60E+07	4,50E+07		1,16E+06		8,72E+06	1,62E+06	
Sr-89		8,00E+06					1,16E+07	2,68E+05	
Sr-90		5,50E+06	1,30E+07	1,40E+06	1,92E+06	5,64E+06	7,45E+06	1,79E+06	2,43E+06
I-131				5,10E+05	1,23E+05	9,73E+05	2,37E+05		
Cs-134								6,43E+06	1,49E+06
Cs-137	2,40E+08	2,20E+08	2,90E+08	3,10E+07	5,78E+07	2,58E+07	3,36E+07	8,75E+07	6,52E+07
Sn-113									
Sn-117m									
Tc-99m						5,17E+05			
Te-123m					3,18E+05				
As-76					1,16E+06		8,37E+06	1,52E+07	5,69E+07
Na-24									
Pu-238		8,40E+0	4,10E+0	3,50E+0	2,87E+0	2,37E+0	5,78E+0	2,14E+0	7,72E+04

		4	5	5	5	5	5	5	
Pu-239/240		1,00E+05	7,20E+04	6,60E+04	1,18E+05	2,60E+04	1,98E+04	3,22E+04	1,80E+04
Am-241		2,00E+05	4,90E+05	5,50E+05	5,40E+05	1,94E+05	5,10E+04	2,37E+05	4,05E+04
Cm-242		1,00E+04	4,20E+03	1,60E+04	5,38E+03		3,63E+04	1,07E+05	1,00E+03
Cm-244		4,20E+04	9,30E+04	5,80E+04	9,67E+04	1,29E+04	1,51E+04	6,40E+04	4,53E+03
Total beta excl H-3	1,26E+09	8,22E+09	2,98E+09	1,10E+09	9,39E+08	4,22E+08	4,89E+08	3,81E+08	3,15E+08
Total alpha	1,30E+07	4,36E+05	1,07E+06	1,00E+06	1,05E+06	4,70E+05	7,00E+05	6,54E+05	1,41E+05

Table 2. *Discharges in Bq/year from Ringhals Unit 2, 2008-2016*

Nuclide	2008	2009	2010	2011	2012	2013	2014	2015	2016
H-3	6,30E+12	1,10E+13	7,20E+12	1,10E+13	3,39E+12	9,92E+12	7,90E+12	1,33E+12	7,47E+11
Cr-51		4,60E+05	7,20E+06	3,80E+06	3,98E+06	1,33E+06	2,74E+05		
Mn-54		2,70E+06	3,50E+06	2,20E+06	1,43E+06	5,28E+05	2,97E+05	5,98E+05	4,14E+05
Fe-59			5,90E+05						
Co-58	1,20E+07	7,70E+06	5,90E+06	1,30E+07	2,55E+06	1,08E+06	3,75E+06	7,04E+05	
Co-60	1,60E+07	2,80E+07	3,20E+07	3,30E+07	2,17E+07	8,13E+06	1,39E+06	4,98E+06	6,85E+06
Ni-63				6,00E+07	1,36E+06	2,27E+07	2,24E+06	1,11E+07	9,70E+07
Zn-65									
Zr-95		1,40E+05		7,20E+05	3,32E+05	1,47E+05			
Nb-95		3,40E+05	5,60E+05	1,30E+06	9,22E+05	4,90E+05			
Zr-95	3,74E+06								
Ag-108m		2,70E+05	5,80E+03						
Ag-110m	2,30E+04	8,70E+07	2,30E+07	1,90E+07	3,76E+07	8,07E+06	4,42E+06	4,95E+06	1,67E+06
Sb-122					1,10E+05		3,65E+05		
Sb-124		5,80E+06	8,00E+06	3,20E+06	3,58E+06	1,41E+06	6,50E+06	1,17E+06	6,42E+04
Sb-125	2,80E+07	8,40E+06	7,00E+06	3,80E+06	2,23E+06	4,69E+05			1,50E+06
Sr-89		2,30E+05		4,60E+04	5,54E+04			5,46E+05	
Sr-90		4,90E+05	9,50E+06	1,60E+06	7,07E+05	1,10E+06	6,63E+05	2,21E+05	5,59E+05
Cs-134									
Cs-137	3,50E+06	5,80E+06	7,60E+06	3,30E+06	3,23E+06	1,71E+06	7,14E+05	1,03E+06	1,70E+06
Te-123m					1,13E+07	7,71E+06	1,83E+05	5,56E+05	
As-76						5,65E+06	7,95E+05		
La-140			3,70E+06						
Ce-144									
Ru-106									
Te-123m				1,20E+06					
Pu-238		2,10E+05	4,30E+05	2,00E+05	4,53E+05	6,28E+03	1,32E+05	1,13E+05	5,77E+04
Pu-239/240		7,40E+04	3,50E+04	4,50E+04	6,15E+04	2,39E+04	1,70E+04	2,93E+04	1,25E+04
Am-241		3,50E+05	2,70E+06	4,50E+05	8,99E+05	5,96E+04	1,64E+05	2,96E+05	8,05E+04
Cm-242		3,70E+03	1,10E+03	8,00E+03	3,92E+04	1,28E+03	4,19E+03	6,05E+03	1,28E+03
Cm-244		9,40E+04	5,80E+04	6,60E+04	9,57E+04	1,82E+04	5,12E+03	8,47E+04	2,34E+04
Total beta excl H-3	4,08E+07	1,47E+08	1,09E+08	1,50E+08	9,11E+07	6,05E+07	2,16E+07	2,59E+07	1,10E+08
Total alpha	7,00E+05	7,32E+05	3,22E+06	7,70E+05	1,55E+06	1,09E+05	3,22E+05	5,29E+05	1,75E+05

Table 3. *Discharges in Bq/year from Ringhals Unit 3, 2008-2016.*

Nuclide	2008	2009	2010	2011	2012	2013	2014	2015	2016
H-3	2,10E+12	2,50E+13	1,70E+13	1,50E+13	6,65E+12	2,14E+13	9,07E+12	2,21E+13	1,92E+13
Na-23			1,30E+05						
Cr-51		8,00E+06	1,00E+07	4,70E+07	4,58E+06	1,71E+07	2,06E+07	2,71E+07	1,32E+07
Mn-54		3,40E+06	4,10E+06	3,00E+06	1,50E+06	2,57E+06	3,54E+06	4,00E+06	3,95E+06
N-13					1,53E+06	4,66E+07			
Fe-59						1,94E+05	2,79E+05	6,65E+05	6,45E+05
Co-57							1,12E+05	2,58E+05	
Co-58	7,20E+05	4,10E+07	3,70E+07	3,90E+07	1,83E+07	8,04E+07	9,24E+07	1,00E+08	5,21E+07
Co-60	1,20E+07	7,50E+07	4,90E+07	3,50E+07	1,63E+07	1,75E+07	2,18E+07	2,74E+07	3,69E+07
Ni-63				1,30E+08	1,53E+06	4,66E+07	5,07E+07	1,80E+08	9,76E+08
Zn-65			1,00E+05	-					5,62E+05
Sr-89				4,50E+04				8,64E+06	
Sr-90				6,50E+06			1,30E+05		2,60E+04
Zr-95	5,50E+05	4,10E+06	4,10E+06	7,30E+06	9,14E+05	2,73E+06	4,57E+06	7,07E+06	6,89E+06
Nb-95		9,60E+06	8,40E+06	1,30E+07	2,03E+06	5,09E+06	7,23E+06	1,23E+07	1,13E+07
Ag-108m				1,40E+05					
Ag-110m	6,00E+06	4,00E+07	5,50E+07	2,10E+07			4,30E+07	4,90E+07	1,39E+08
Sb-122			1,00E+06	-					
Sb-124		1,80E+07	3,00E+08	5,00E+07	2,42E+07	1,76E+07	7,74E+06	1,15E+07	1,08E+07
Sb-125	1,40E+06	1,20E+07	7,00E+07	6,50E+06	1,41E+07	1,75E+07	5,52E+06	2,16E+07	5,01E+06
Te-123m				2,00E+07	3,01E+07	2,12E+07	2,99E+07	5,98E+07	
Cs-134				-					
Cs-137	1,70E+05	6,80E+05	1,40E+06	7,60E+05	6,39E+05	1,24E+06	7,80E+05	8,92E+05	2,76E+05
Ce-144				-					
Sn-113						1,31E+05	7,93E+04	2,43E+05	
Sn-117m							6,74E+04		
Tc-99m									
As-76									
Na-24						3,93E+05			
Pu-238		4,20E+05	3,40E+05	2,20E+05	2,60E+05	1,44E+04	6,38E+04	2,38E+05	1,66E+05
Pu-239/240		8,40E+03	3,00E+04	2,90E+04	4,37E+04	3,08E+04	9,19E+03	2,45E+04	3,09E+04
Am-241		3,50E+05	5,80E+05	4,10E+05	4,44E+05	3,73E+04	2,51E+05	1,61E+05	3,79E+04
Cm-242		1,40E+04		-	1,27E+03	2,31E+02		1,36E+04	8,98E+02
Cm-244		2,70E+03	6,50E+02	2,90E+04	9,56E+02	5,73E+02	1,26E+03	1,20E+04	5,49E+03
Total beta excl H-3	3,38E+08	2,12E+08	5,40E+08	3,80E+08	1,16E+08	2,77E+08	2,88E+08	5,10E+08	1,26E+09
Total alpha	4,00E+04	7,95E+05	9,51E+05	6,90E+05	7,50E+05	8,33E+04	3,25E+05	4,49E+05	2,41E+05

Table 4. *Discharges in Bq/year from Ringhals Unit 4, 2008-2016.*

Nuclide	2008	2009	2010	2011	2012	2013	2014	2015	2016
H-3	1,10E+13	9,00E+12	1,60E+13	1,10E+13	1,26E+13	9,79E+12	2,04E+13	9,96E+12	1,32E+13
Cr-51		5,70E+07	2,30E+07	2,00E+07	1,49E+07	1,96E+06	1,11E+07	1,93E+07	6,07E+06
Mn-54		4,20E+06	4,80E+06	7,30E+06	4,45E+06	3,27E+06	1,84E+06	2,71E+06	1,77E+06
Fe-59		3,40E+06	3,00E+06	4,70E+06	1,59E+06	2,08E+05	1,66E+06	1,20E+06	4,23E+05
Co-57		1,60E+06	2,20E+06	3,40E-06	1,86E+06	9,02E+05	8,15E+05	6,87E+05	4,55E+05
Co-58	1,10E+09	4,30E+08	6,00E+08	6,50E+08	2,68E+08	2,54E+08	1,85E+08	3,34E+08	1,61E+08
Co-60	7,50E+07	3,80E+07	2,90E+07	3,20E+07	2,10E+07	9,49E+06	9,55E+06	1,15E+07	1,07E+07
Ni-63				1,80E+08	2,28E+06	8,88E+07	7,45E+07	1,64E+08	1,28E+08
Zn-65	4,00E+05			-				3,98E+06	2,42E+05
Sr-89				1,20E+07			1,57E+06	3,33E+06	
Sr-90				-			3,54E+05		
Zr-95	1,23E+08	9,60E+06	6,50E+06	7,80E+06	1,82E+06	5,19E+05	1,25E+06	2,18E+06	9,48E+05
Nb-95		1,70E+07	1,10E+07	1,50E+07	3,57E+06	1,02E+06	2,05E+06	3,39E+06	1,10E+06
Ag-110m	1,23E+06	6,10E+05	6,80E+05	3,20E+06	7,93E+05	1,78E+06	1,40E+07	2,01E+07	1,37E+07
Sn-113		2,60E+05	1,40E+05	2,20E+05					
Sn-117m							7,66E+05		
Sb-122									
Sb-124		4,60E+06	2,20E+06	1,40E+07	1,93E+06	9,36E+05	9,17E+05	2,22E+07	2,88E+06
Sb-125		1,20E+06	1,80E+06	6,40E+06	8,33E+06	3,72E+05		1,29E+07	
Te-123m				7,00E+06					
I-131								1,19E+06	
Cs-134				-				1,29E+06	
Cs-137	4,10E+06	7,40E+05	4,70E+05	1,10E+05		3,30E+05	3,04E+05	2,34E+06	6,07E+05
Ce-144	1,20E+06			-					
Tc-99m									
Te-123m					2,53E+06	8,37E+04		7,86E+06	
As-76									
Na-24									
Pu-238		3,00E+04	2,30E+05	3,00E+05	1,77E+05	3,70E+04	3,41E+04	2,52E+05	1,11E+05
Pu-239/240		1,50E+04	2,50E+04	5,00E+04	3,20E+04	3,37E+03	1,24E+03	2,51E+04	2,21E+04
Am-241		1,30E+04	3,50E+05	5,20E+05	2,84E+05	2,45E+04	9,21E+04	1,59E+05	1,63E+04
Cm-242			1,70E+03	2,90E+02	1,01E+03	1,73E+02		2,20E+03	2,61E+03
Cm-244		1,80E+02	2,70E+03	8,60E+04	9,98E+01	8,70E+01	1,08E+02	1,78E+03	4,38E+03
Total beta excl H-3	2,80E+09	5,68E+08	6,85E+08	9,60E+08	3,33E+08	3,64E+08	3,06E+08	6,14E+08	3,28E+08
Total alpha	5,30E+05	5,82E+04	6,09E+05	9,60E+05	4,94E+05	6,51E+04	1,28E+05	4,40E+05	1,56E+05

Table 5. *Annual discharges of total beta exclusive H-3 and H-3 from Ringhals normalized to energy production (GBq/Gwa)*

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ringhals 1									
beta excl H-3	2,40E+00	5,54E+01	7,25E+00	1,61E+00	1,50E+00	6,06E-01	7,79E-01	5,76E-01	4,24E-01
H-3	9,90E-01	2,43E+00	9,25E-01	7,15E-01	6,74E-01	5,97E-01	6,37E-01	1,66E+00	8,07E-01
Ringhals 2									
beta excl H-3	6,27E-02	4,77E-01	1,71E-01	7,73E-01	2,22E-01	8,42E-02	4,40E-02		1,37E+00
H-3	9,68E+00	3,57E+01	1,13E+01	5,67E+01	8,25E+00	1,38E+01	1,61E+01		9,35E+00
Ringhals 3									
beta excl H-3	3,90E-01	2,29E-01	6,22E-01	4,69E-01	1,22E-01	3,51E-01	3,12E-01	5,81E-01	1,49E+00
H-3	2,42E+00	2,70E+01	1,96E+01	1,85E+01	7,02E+00	2,72E+01	9,81E+00	2,51E+01	2,27E+01
Ringhals 4									
beta excl H-3	3,36E+00	6,63E-01	8,33E-01	2,05E+00	4,17E-01	4,31E-01	4,00E-01	7,08E-01	3,46E-01
H-3	1,32E+01	1,05E+01	1,95E+01	2,35E+01	1,58E+01	1,16E+01	2,67E+01	1,15E+01	1,39E+01

Table 6. *Emissions of carbon-14 and tritium (Bq/year) (both oxidised and reduced chemical forms included)*

Bq/year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ringhals 1									
C-14	3,8E+11	1,14E+11	2,48E+11	4,47E+11	3,73E+11	4,21E+11	7,43E+11	8,2E+11	
H-3	2,97E+11	3,88E+10	5,87E+10	1,33E+11	9,07E+10	1,09E+11	2,15E+11	5,34E+11	
Ringhals 2									
C-14	1,96E+11	1,04E+11	1,13E+11	1,59E+11	5,97E+10	2,03E+11	4,05E+11	4,4E+10	5,1E+09
H-3	2,92E+11	3,3E+11	4,96E+11	4,64E+11	3,76E+11	4,63E+11	1,82E+12	1,28E+12	8,37E+11
Ringhals 3									
C-14	1,77E+11	2,55E+11	2,27E+11	1,93E+11	1,33E+11	2,67E+11	4,17E+11	6,61E+11	5,15E+11
H-3	8,86E+11	1,03E+12	6,73E+11	9,19E+11	7,75E+11	5,23E+11	9,52E+11	1,08E+12	1,47E+12
Ringhals 4									
C-14	1,08E+11	2,07E+11	2,43E+11	1,45E+11	1,88E+11	2,2E+11	4,08E+11	4,22E+11	4,65E+11
H-3	7,79E+11	7,11E+11	7E+11	4,99E+11	6,91E+11	6,22E+11	1,61E+12	1,66E+12	2,12E+12

Table 7. *Concentrations of Co-60 and Cs.137 in sediment from station 3, (close to outlet), in Ringhals environmental monitoring program.*

RAB_3	***Co-60***	***Cs-137***	***Co-58***	***Mn-54***	***Nb-95***
2002-03-25	*1,99E+00*	*1,87E+00*	*<*	*<*	*<*
2002-06-24	*4,05E+00*	*5,18E+00*	*<*	*<*	*<*
2002-09-30	*6,13E+00*	*6,04E+00*	*<*	*<*	*4,57E-01*
2002-12-12	*9,43E+00*	*2,93E+00*	*8,95E-01*	*<*	*<*
2003-03-27	*3,71E+00*	*3,11E+00*	*<*	*<*	*<*
2003-06-16	*3,45E+00*	*2,34E+00*	*9,05E-01*	*<*	*1,03E+00*
2003-09-30	*4,71E+00*	*2,17E+00*	*4,53E-01*	*5,56E-01*	*<*
2003-12-02	*1,83E+00*	*1,67E+00*	*<*	*<*	*8,15E-01*
2004-03-24	*1,99E+00*	*1,94E+00*	*<*	*<*	*<*
2004-06-01	*1,59E+01*	*2,00E+00*	*<*	*<*	*<*
2004-09-30	*3,04E+00*	*1,45E+00*	*<*	*<*	*<*
2004-11-29	*1,10E+00*	*1,43E+00*	*<*	*<*	*<*
2005-03-23	*1,46E+00*	*1,51E+00*	*<*	*<*	*<*
2005-05-27	*1,62E+00*	*1,84E+00*	*<*	*<*	*<*
2005-09-23	*1,20E+00*	*1,56E+00*	*6,12E-01*	*<*	*<*
2005-12-27	*1,10E+00*	*1,22E+00*	*<*	*<*	*<*

2006-03-31	*2,22E+00*	*1,79E+00*	*<*	*<*	*<*
2006-06-08	*5,48E-02*	*1,90E+00*	*<*	*2,30E-01*	*<*
2006-09-29	*6,34E-01*	*1,04E+00*	*<*	*<*	*<*
2006-11-30	*2,00E-01*	*1,65E+00*	*<*	*<*	*<*
2007-03-22	*<*	*2,38E+00*	*<*	*<*	*<*
2007-05-21	*5,49E-01*	*1,40E+00*	*<*	*<*	*<*
2007-08-31	*4,72E-01*	*1,65E+00*	*<*	*<*	*<*
2007-12-11	*6,39E-01*	*1,50E+00*	*<*	*<*	*<*
2008-03-16	*6,00E-01*	*1,34E+00*	*<*	*<*	*<*
2008-05-30	*5,28E-01*	*2,00E+00*	*<*	*<*	*<*
2008-09-19	*6,95E-01*	*1,66E+00*	*<*	*<*	*<*
2008-12-17	*5,02E-01*	*1,61E+00*	*<*	*<*	*<*
2009-03-10	*5,50E-01*	*1,49E+00*	*<*	*<*	*<*
2009-06-01	*8,99E-01*	*1,35E+00*	*<*	*<*	*<*
2009-09-10	*<*	*1,10E+00*	*<*	*<*	*<*
2009-11-30	*2,45E-01*	*1,43E+00*	*<*	*<*	*<*
2010-03-30	*4,58E-01*	*1,47E+00*	*<*	*<*	*<*
2010-06-23	*4,97E-01*	*1,58E+00*	*<*	*<*	*<*
2010-09-30	*<*	*1,17E+00*	*<*	*<*	*<*
2010-11-30	*7,16E-01*	*1,40E+00*	*<*	*<*	*<*
2011-03-28	*5,87E-01*	*1,35E+00*	*<*	*<*	*<*
2011-05-31	*3,55E-01*	*1,19E+00*	*<*	*<*	*<*
2011-09-30	*3,14E-01*	*1,28E+00*	*5,63E-01*	*<*	*<*
2011-12-08	*<*	*1,03E+00*	*<*	*<*	*<*
2012-03-14	*<*	*1,29E+00*	*<*	*<*	*<*
2012-06-29	*2,83E-01*	*1,26E+00*	*<*	*<*	*<*
2012-09-27	*<*	*7,28E-01*	*<*	*<*	*<*
2012-12-19	*3,63E-01*	*1,33E+00*	*<*	*<*	*<*
2013-04-02	*7,51E-01*	*1,35E+00*	*<*	*<*	*<*
2013-06-19	*1,69E-01*	*9,04E-01*	*<*	*<*	*<*
2013-09-27	*<*	*9,18E-01*	*<*	*<*	*<*
2013-12-09	*<*	*1,00E+00*	*<*	*<*	*<*
2014-04-03	*2,50E-01*	*1,26E+00*	*<*	*<*	*<*
2014-06-27	*<*	*9,32E-01*	*<*	*<*	*<*
2014-09-29	*2,74E-01*	*1,01E+00*	*<*	*<*	*<*

2015-08-27	*<*	*9,72E-01*	*<*	*<*	*<*
2015-11-26	*<*	*9,22E-01*	*<*	*<*	*<*
2016-10-04	*<*	*8,66E-01*	*<*	*<*	*<*
2016-12-04	*<*	*8,31E-01*	*<*	*<*	*<*

Table 8 *Cs-137 concentrations in bladder wrack (Fucus Vesiculosus) (Bq kg^{-1} fresh wt) in three sample location in subdivision 12*

.

date	Ringhals (R13)	Ringhals (R25)	Ringhals (R3)	Ringhals (R7)
2000-04-19		1,08E+00		
2000-09-28		1,47E+00		
2001-09-25		1,40E+00		
2002-09-25		1,76E+00		
2003-09-30		1,33E+00		
2004-04-26		9,34E-01		
2004-09-30		1,19E+00		
2005-10-24		1,44E+00		
2006-10-09		1,06E+00		
2007-10-01		7,16E-01		
2008-05-08		1,66E+00		
2008-11-03		4,98E-01		
2009-09-17		5,74E-01		
2010-10-15		6,46E-01		
2011-11-07		5,30E-01		
2012-05-24		6,84E-01		
2013-09-19	2,56E-01			
2013-09-20				4,58E-01
2013-09-27		3,86E-01	3,40E-01	
2014-09-02				5,30E-01
2014-09-04	4,18E-01	4,82E-01	3,84E-01	
2015-09-09	3,10E-01		3,88E-01	4,90E-01
2015-09-21		3,80E-01		
2016-05-13			6,40E-01	
2016-05-17	8,38E-01			7,50E-01
2016-05-24		7,20E-01		

Strålsäkerhetsmyndigheten
Swedish Radiation Safety Authority

SE-171 16 Stockholm
Solna strandväg 96

Tel:+46 8 799 40 00
Fax:+46 8 799 40 10

E-post: registrator@ssm.se
Webb: stralsakerhetsmyndigheten.se

OSPAR COMMISSION

Victoria House
37-63 Southampton Row
London WC1B 4DA
United Kingdom

t: +44 (0)20 7430 5200
f: +44 (0)20 7242 3737
e: secretariat@ospar.org
www.ospar.org

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