

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



**OSPAR Commission
2005**

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. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

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. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, 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 et la Suisse et approuvée par la Communauté européenne et l'Espagne.

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1. Background

The PARCOM Recommendation 91/4 concerns application 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. 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.

Sweden first reported compliance with PARCOM Recommendation 91/4 in 1992. With regard to the first round of implementation reports, the Progress Report of the 4th North Sea Conference concluded that Sweden was one of the Contracting Parties for which the first 4-year-cycle of reviewing national implementation of PARCOM Recommendation 91/4 has been completed satisfactorily. Sufficient information was received and the Oslo and Paris Commissions did not identify any failure to apply BAT. It was also concluded, however, that for Sweden as well as other Contracting Parties the absence of agreed criteria to apply BAT limited the possibility of more positive conclusions.

For the second round of implementation reporting, the Working Group on Radioactive Substances (RAD) and subsequently the Programmes and Measures Committee (PRAM) adopted new guidelines to be used on a trial basis to assess application of BAT [RAD 96/6/1]. Sweden reported compliance with PARCOM Recommendation 91/4 within the second round in 1996 [RAD 96/5/4]. RAD concluded [RAD 99/14/1], with regard to the implementation reports received during the second round of reporting, that Contracting Parties had fulfilled the reporting requirements of PARCOM Recommendation 91/4 and that all reports had been in line with the guidelines adopted by PRAM in 1995. There were no indications that BAT had not been applied in the nuclear installations of these Contracting Parties. The conclusions were not supported by Ireland.

Following the experience gained during the two first implementation rounds, including the failure of the existing guidelines to positively identify BAT, revised guidelines for reporting and assessment were used on a trial basis in the third implementation round [OSPAR reference number 1999:11]. According to these guidelines, Sweden reported compliance with PARCOM Recommendation 91/4 in 2000 [RAD 00/4/3]. RAD [RAD 2000 Summary Record, Agenda Item 4], and the Radioactive Substances Committee (RSC) [RSC 2001 Summary Record, Agenda Item 5; RSC 2002 Summary Record, Agenda Item 5] concluded that all Contracting Parties had fulfilled the reporting requirements, that the reports were in line with the guidelines, and that the information presented included indications that BAT had been applied in the nuclear installations. The conclusions were not supported by Ireland and Norway.

Following an evaluation of the third round of implementation reports, RSC 2003 agreed to revise the Guidelines. The revision should take 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] that 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 should be used in the fourth implementation round.

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. The report covers the years 1998-2003. Following the previous three reports from Sweden, information is also provided for the Barsebäck nuclear power plant, which discharges in close proximity to the Convention waters.

2. General information

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

According to the Guidelines, this section mainly considers legislation and regulations that are new or changed since the latest implementation round as described in the Swedish report from 2000 [RAD 00/4/3]. A more complete description of the legal situation in Sweden is given in that report.

2.1.1 The Radiation Protection Act

The aim of the Radiation Protection Act [SFS 1988:220, amended 1990:236, 1992:1205, 1995:69, 1995:874, 1998:841, 2000:264, 2000:1068, 2000:1242, 2000:1287, 2004:456] 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*). 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 Radiation Protection Ordinance (1988:293, amended 1990:1193, 1991:1635, 1992:1541, 1995:212, 1998:893, 2000:809, 2001:618) contains details pursuant to authorisation in the Radiation Protection Act. The Ordinance authorises the Swedish Radiation Protection Authority (SSI) to act as the central administrative authority in the area of radiation protection. The SSI may issue regulations [SSI Code of Statutes, SSI FS], based on authorisation in the Radiation Protection Ordinance. The SSI is also responsible for the surveillance of the activities of the operator.

2.1.2 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 ionising radiation in the environment. Such activities are categorised as 'environmentally hazardous', together with numerous other activities [9 Chapter 1 § SFS 1998:808]. 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 3 § SFS 1998:808].

2.1.3 Regulations issued by the SSI

On the basis of the authorisation granted in the Radiation Protection Ordinance, SSI has issued 'Regulations on the Protection of Human Health and the Environment from the releases of Radioactive Substances from Certain Nuclear Facilities' [SSI FS 2000:12]. 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 (SSI FS 1998:1) 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.

2.2 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, but the limit has been in use in Sweden since 1990, following the entering into force of SSI Regulations on dose limits in practices involving ionising radiation etc. [SSI FS 1989:1, revised SSI FS 1998:4].

According to the regulations [SSI FS 2000:12] 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 radiation, 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.

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.

2.3 Discharge limits

SSI 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 contribution 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.

2.4 Monitoring programmes of environmental concentrations of radionuclides

The regulations [SSI FS 2000:12] 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 Protection 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 SSI (latest version, SSI Dnr 611/178/99) and specify 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, SSI performs inspections and takes random sub-samples for measurements at the SSI 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 and Barsebäck NPPs are specified in further detail in Tables 2.2 and 2.3. The compulsory nuclide library used in environmental monitoring is given in Table 2.4.

Table 2.2. Overview of marine environmental sampling at Ringhals and Barsebäck nuclear power plants

Type of sample	Number of sampling stations		Period S= Spring, A= Autumn
	Barsebäck	Ringhals	
Seawater	1	1	Quarterly
Sediment	1	2	Quarterly
		1	A
Algae			
Green algae, <i>Cladophora sp.</i>	2	2	A
Bladder wrack, <i>Fucus vesiculosus</i>	5	7	A
<i>Fucus serratus</i>	2		A
Diatomic algae	1	2	Monthly
Molluscs & Arthropods			
<i>Littorina</i>		2	A
Sea mussel, <i>Mytilus edulis</i>	3	3	A
Lobster, <i>Homarus gammarus</i>		1	A
Crab, <i>Cancer pagurus</i>		1	A
Fish			
Eel, <i>Anguilla anguilla</i>	2	3	SA
Cod, <i>Gadus morrhua</i>	1	1	A
Plaice, <i>Platichthys flesus</i>	1		SA
Corkwing, <i>Crenilabrus melops</i>		1	SA
Herring, <i>Clupea harengus</i>	1		A
Scorpion fish, <i>Myoxocephalus scorpius</i>	1	1	SA

Table 2.3. Overview of extended programme, to be executed every fourth year

Type of sampling	Number of additional sampling stations	
	Barsebäck	Ringhals
Algae		
Green algae, <i>Cladophora sp.</i>	4	4
Bladder wrack, <i>Fucus vesiculosus</i>	9	9
Molluscs		
<i>Littorina sp.</i>		3
Sea mussel, <i>Mytilus edulis</i>	4	5
Sediment	11	13

Table 2.4. 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 SSI in 1999-2000 (SSI-report 2000:13) and the programme is now being extensively revised. The new programme will be issued in 2005.

The regulations (SSI FS 2000:12) 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 SSI so decides. The extent and design of these investigations is decided from case to case by the SSI 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 SSI does not decide otherwise, be reported to the SSI 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 luminescence detectors, TLD's) are evaluated quarterly and the results are reported to SSI. 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.

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

The Swedish Parliament has approved 15 national goals for environmental quality. One goal, 'Safe radiation environment' includes the target that by the year 2010, the concentrations in the environment of radioactive substances released from all practices involving ionizing radiation shall be so low that human health and the biological diversity are protected. The dose to individuals shall not exceed 10 microsievert a year from any practice.

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.

An international research initiative, co-ordinated by the SSI and financed by the EC 5th Framework Programme, has presented its results in May 2004. An overview of the achievements is given in the final report 'Framework for Assessment of Environmental Impact (FASSET)¹. The assessment framework developed under FASSET includes the following fundamental elements: selection of a number of reference organisms on the basis of prior ecosystem and exposure analysis; environmental transfer analysis; dosimetric considerations; effects analysis; and, as an integral part of the aforementioned steps, general guidance on interpretation, including consideration of uncertainties and possibilities to extrapolate from existing data to areas where data are absent or scarce. The FASSET project is developed further and extended in ERICA, Environmental Risk from Ionising Contaminants: Assessment and Management, which is part of the EC 6th Framework Programme (see footnote 1). The objective of ERICA is to provide an integrated approach to scientific, managerial and societal issues concerned with the environmental effects of contaminants emitting ionising radiation, with emphasis on biota and ecosystems.

2.6 National authority responsible for supervision of discharges

The Swedish Radiation Protection Authority, SSI (see also Section 2.1.1) is the national authority responsible for supervision including the regulation of the releases of radioactive substances from nuclear facilities.

2.7 Nature of inspection and surveillance programmes

SSI regularly 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 SSI 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 SSI 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 SSI. The annual samples are measured concerning gamma emitters and tritium by the SSI and the results are compared with the data submitted by the operators. These measurements are conducted at the SSI

¹ The report is available on the web-site www.ERICA-project.org

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 SSI 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 SSI. 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.

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

Monitoring data shall, according to the SSI Regulations on Archives at Nuclear Facilities [SSI FS 1997:1], 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.

3. Site-specific information – Ringhals nuclear power plant

3.1 Site characteristics

3.1.1 Name of site

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

3.1.2 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.

3.1.3 Start of operations

The start of operations for the four reactor units are given in Table 3.1.

Table 3.1. 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

3.1.4 Location

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

3.1.5 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.

3.1.6 Production

The installed electrical effect (MW_e) and the annual electrical output (GWa) for the years 1998-2003 are given in Table 3.2.

Table 3.2. Installed electrical effect and net electrical output, Ringhals units 1 - 4

Unit	1	2	3	4
Gross Power, MW _e	860	917	960	960
Net Power, MW _e	830	875	915	915
Year	Net GWa			
1998	0,639	0,696	0,732	0,777
1999	0,569	0,746	0,805	0,811
2000	0,371	0,592	0,707	0,465
2001	0,672	0,732	0,727	0,766
2002	0,682	0,759	0,798	0,686
2003	0,583	0,789	0,776	0,813

3.1.7 Other relevant information

There is no other relevant information.

3.2 Discharges

3.2.1 Systems in place to reduce, prevent or eliminate discharges and emissions

The liquid waste to be discharged is purified by particle filtration 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 dose to the critical group rather than on the activity content. Evaporation of liquid waste is not used, since the evaporators installed have too low capacity to process the amount of liquid. However, in the recycling of boron in the PWR-units, evaporation is used. A summary of the systems in place to reduce, prevent or eliminate discharges to the marine environment are given in Tables 3.3-3.6.

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 3.4). During normal operations it handles the full volume of waste water. However, it can not handle the large volumes of water that are discharged in a shut-down transient situation.

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 3.3-3.6). For the three PWRs, some highly contaminated waters are transferred to Ringhals 1 waste treatment plant.

3.2.2 Systems to reduce, prevent and eliminate emissions

In 1998 (Table 3.3) 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.

3.2.3 Efficiency of abatement systems

The efficiencies of the abatement systems in place in the four Ringhals reactors are summarised in Tables 3.3-3.6.

The performance of the liquid waste handling systems depends of several factors that are 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 3.3. 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	Deconta- mination 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
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. 1997-2003 only 2 cases of fuel leakage. 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. Debris catchers in feedwater lines.
Minimising air leakage into turbine systems	Ca 1996			Improved delay time by 2-3 times. This is necessary to obtain good effect of recombiners	
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 3.4. 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	Deconta- mination 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 not 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 leakages during 1997- 2003 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	
Separation of waste streams for improved treatments. Some highly contaminated waters are transferred to Ringhals 1 waste treatment plant.	Ca 2000			n.a.	

Table 3.5. 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	Deconta- mination Factor	Other measure of efficiency	
Discharges:					
Particulate filtration	1981		5-10		
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%		
Changes in management or processes:					
Non fuel-leakage operations policy	1995			Reduction of number of leaking fuel. 1997-2003 there were only 2 cases. 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. keeping clean during maintenance work and in and around fuel pools.
Separation of waste streams for improved treatments. Some highly contaminated waters are transferred to Ringhals 1 waste treatment plant.	1999		>10		
Programme for pH- and red-ox operational control and oxidising system clean-up operation during shut- down.	Early 80s			Lower dose rates on system sur- faces and less activity spread in plant.	

Table 3.6. 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	Deconta- mination Factor	Other measure of efficiency	
Discharges:					
Particulate filtration	1983		5-10		
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%		
Changes in management or processes:					
Non fuel-leakage operations policy	1995			Reduction of number of leaking fuel. 1997-2003 there were 4 cases. 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. 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 sur- faces and less activity spread in plant.	
Separation of waste streams for improved treatments. Some highly contaminated waters are transferred to Ringhals 1 waste treatment plant.	1999		>10		

3.2.4 Annual liquid discharges

ABSOLUTE DISCHARGES

The absolute discharges of total beta 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 3.7 – 3.10 and Figures 3.1 – 3.4.

Replacements of control rods during the late nineties in R2, R3 and R4 have reduced the source of Ag-110m and as a consequence also the discharges of the nuclide.

Leaking fuel rods were detected and removed in Ringhals 1 in 2000, in Ringhals 3 in 1999 and 2004 and also in Ringhals 4 in 2001, 2002, 2003.

The discharges have in recent years returned to values characteristic of long-term performance in the absence of fuel failures. 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.

Table 3.7. Discharges in Bq from Ringhals Unit 1, 1998-2003

Nuclide	1998	1999	2000	2001	2002	2003
H-3	5,49E+11	9,86E+11	5,14E+11	6,73E+11	7,36E+11	9,84E+11
Co-58	3,04E+09	4,25E+09	9,55E+08	8,80E+08	8,28E+08	7,53E+08
Co-60	2,98E+10	1,42E+10	8,60E+09	1,69E+10	3,53E+09	2,26E+09
Zn-65	8,87E+07	2,95E+07	1,65E+06	6,28E+06	2,59E+06	1,26E+07
Sr-90	3,47E+07	2,48E+07	1,17E+07	2,39E+06	1,01E+07	7,40E+06
Zr/Nb-95	1,72E+08	2,67E+09	1,21E+08	1,24E+08	9,51E+07	1,49E+08
Ru-106	3,05E+07	2,99E+07				
Ag-110m	3,22E+08	2,41E+08	9,42E+07	1,34E+08	1,77E+08	1,73E+08
Sb-125	1,37E+08	6,13E+08	8,46E+07	9,83E+07	8,47E+07	5,12E+07
Cs-134	9,54E+08	1,48E+08	3,04E+07	5,29E+06	4,76E+07	2,90E+07
Cs-137	1,02E+10	2,26E+09	4,21E+08	4,90E+08	6,47E+08	5,86E+08
Ce-144		3,60E+07				
Other nuclides	7,65E+09	4,92E+09	1,07E+09	1,47E+09	1,28E+09	1,00E+09
Total beta excl H-3)	5,24E+10	2,94E+10	1,14E+10	2,01E+10	6,70E+09	5,03E+09
Total alpha	1,10E+07	2,96E+06	3,20E+06	3,19E+06	1,09E+06	5,98E+05

Figure 3.1A. Discharges in Bq from Ringhals Unit 1, 1998-2003, for H-3, total alpha and total beta excl. H-3

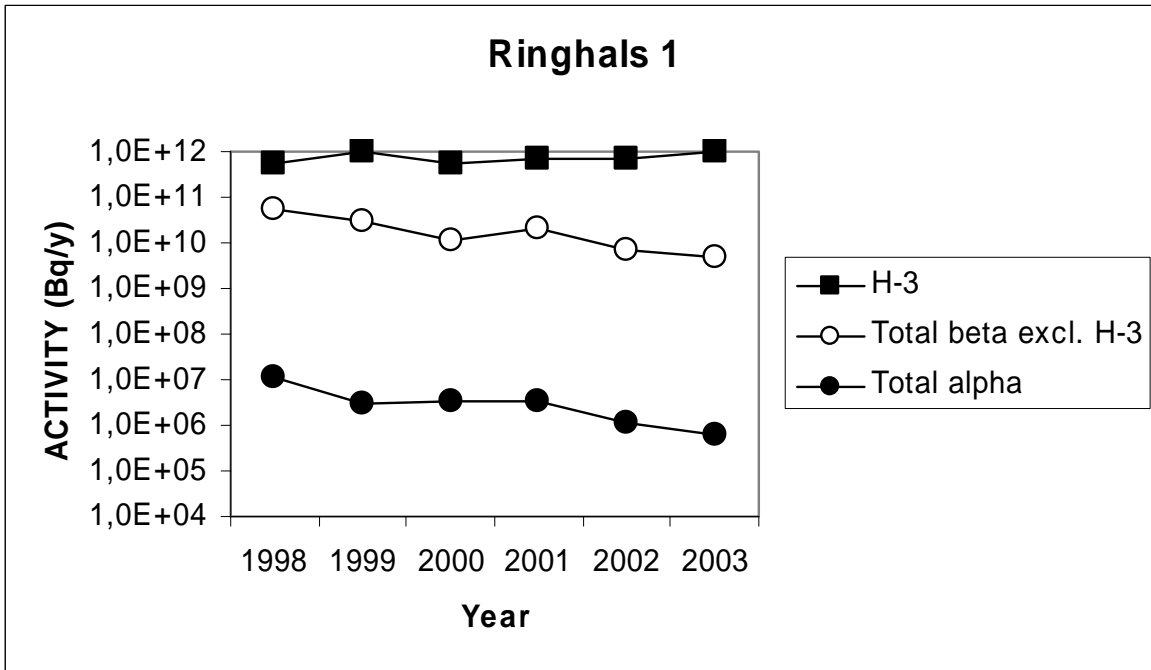


Figure 3.1B. Nuclide specific discharges in Bq from Ringhals Unit 1, 1998-2003

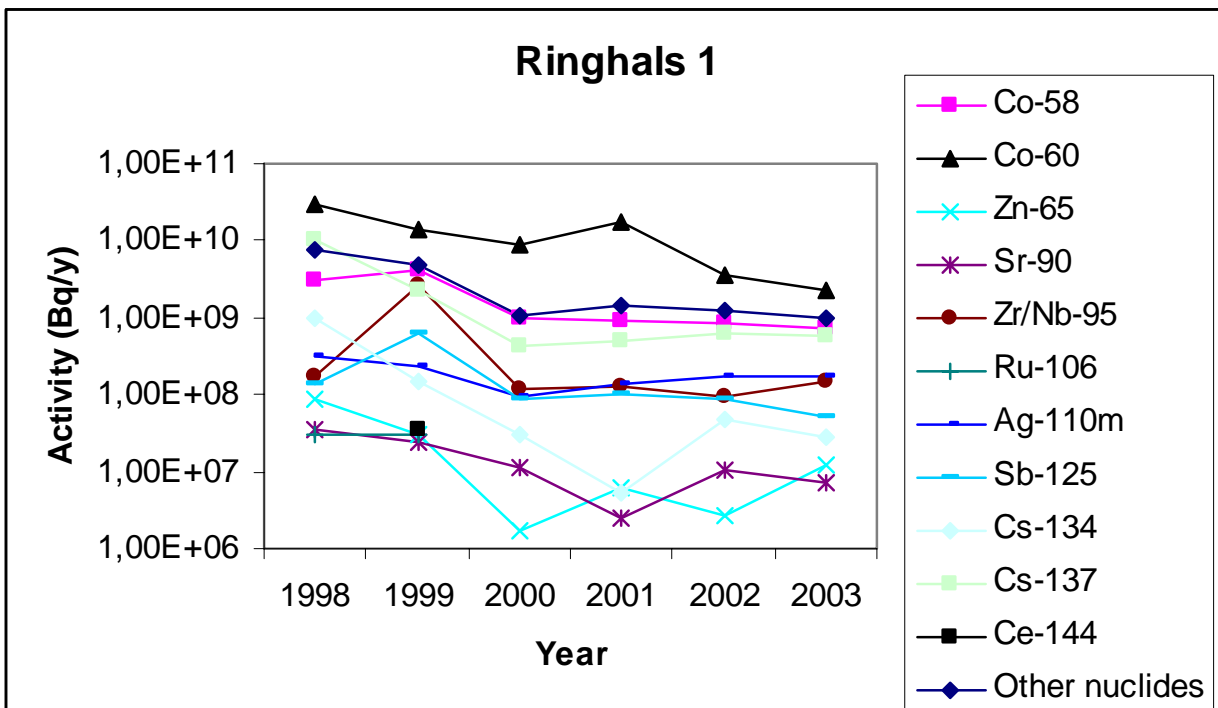


Table 3.8. Discharges in Bq from Ringhals Unit 2, 1998-2003

Nuclide	1998	1999	2000	2001	2002	2003
H-3	8,49E+12	1,41E+13	1,12E+13	1,05E+13	8,67E+12	1,66E+13
Co-58	1,23E+10	1,20E+09	1,25E+09	3,78E+08	1,48E+09	1,33E+09
Co-60	3,44E+09	6,94E+08	1,34E+09	4,63E+08	9,88E+08	2,75E+08
Zn-65	4,11E+07	6,86E+06	1,10E+07	2,77E+06	7,79E+06	2,03E+06
Sr-90	6,10E+06	4,01E+06	4,10E+06	8,45E+05	1,27E+06	3,71E+05
Zr/Nb-95	7,08E+08	2,07E+08	1,44E+08	5,92E+07	6,98E+07	1,23E+08
Ru-106	3,35E+08	6,50E+07	1,52E+07		1,14E+06	
Ag-110m	2,74E+09	2,49E+08	6,54E+08	6,92E+08	8,02E+08	2,79E+08
Sb-125	1,86E+08	1,77E+08	1,23E+09	9,12E+08	7,75E+08	7,47E+08
Cs-134	1,66E+05			7,94E+06		
Cs-137	1,50E+07	9,84E+06	1,28E+07	3,79E+07	9,99E+06	2,39E+07
Ce-144	1,46E+06			2,77E+06	1,34E+05	
Other nuclides	4,91E+09	2,08E+09	3,54E+09	9,33E+09	2,73E+09	3,25E+09
Total beta excl H-3	2,47E+10	4,71E+09	8,20E+09	1,19E+10	6,86E+09	6,03E+09
Total alpha	3,60E+06	5,25E+05	1,16E+06	3,72E+05	3,17E+05	4,42E+04

Figure 3.2A. Discharges in Bq from Ringhals Unit 2, 1998-2003, for H-3, total alpha and total beta excl H-3

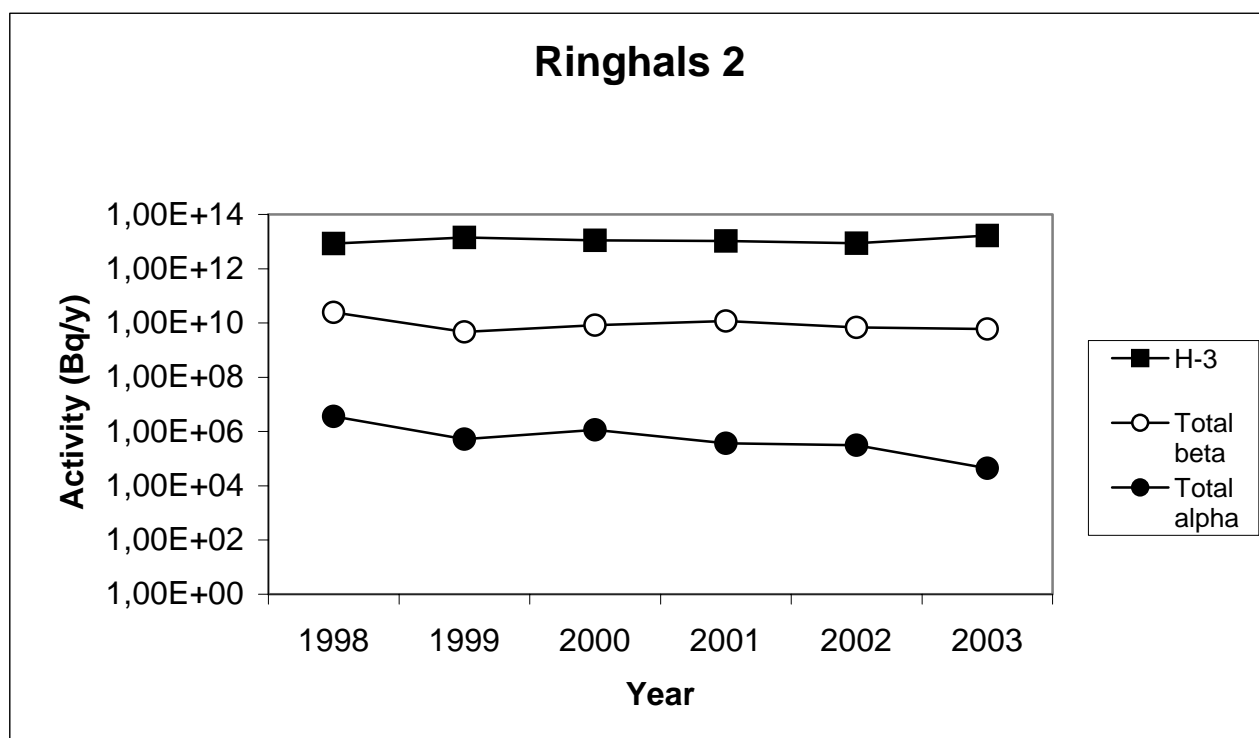


Figure 3.2B. Nuclide specific discharges in Bq from Ringhals Unit 2, 1998-2003

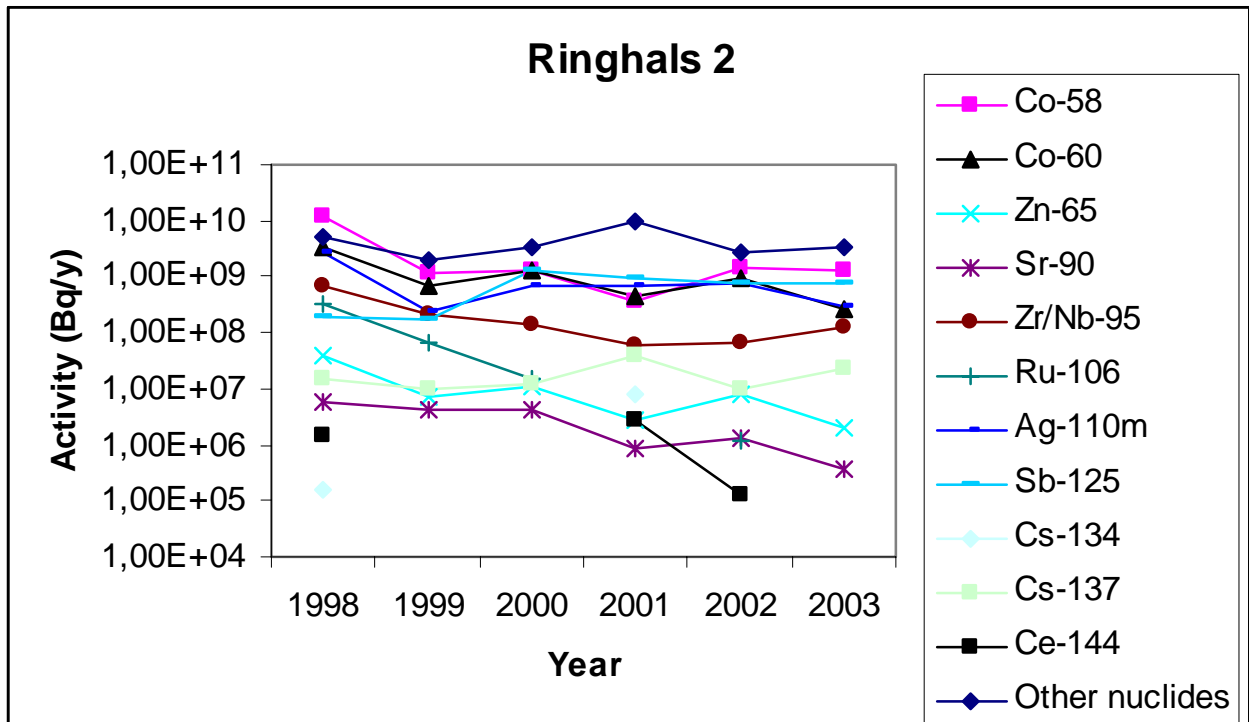


Table 3.9. Discharges in Bq from Ringhals Unit 3, 1998-2003

Nuclide	1998	1999	2000	2001	2002	2003
H-3	6,79E+12	1,13E+13	9,04E+12	9,18E+12	7,23E+12	9,87E+12
Co-58	5,98E+09	1,82E+10	7,62E+09	1,77E+10	7,92E+09	5,38E+09
Co-60	8,12E+08	1,37E+09	9,90E+08	1,55E+09	5,65E+08	4,73E+08
Zn-65	8,42E+06	2,87E+07	1,77E+07	3,38E+07	8,93E+06	8,39E+06
Sr-90	3,99E+06					5,25E+05
Zr/Nb-95	2,55E+08	6,48E+08	4,15E+08	9,07E+08	1,75E+08	2,37E+08
Ru-106	3,51E+08	1,50E+08	1,64E+07			
Ag-110m	2,47E+09	2,18E+09	4,19E+08	4,57E+08	1,24E+08	1,95E+08
Sb-125	4,05E+08	9,35E+07	7,40E+07	1,40E+08	7,02E+07	1,46E+08
Cs-134	2,93E+06	2,07E+07	1,73E+06		8,50E+05	2,49E+06
Cs-137	9,53E+06	1,86E+07	8,59E+06	3,55E+07	1,06E+07	9,59E+06
Ce-144	9,50E+06	3,15E+06	1,86E+06	6,42E+06		
Other nuclides	1,08E+09	1,78E+09	1,32E+09	2,81E+09	7,60E+08	1,28E+09
Total beta excl H-3	1,14E+10	2,45E+10	1,09E+10	2,36E+10	9,60E+09	7,93E+09
Total alpha	4,90E+05	4,10E+05	6,94E+04	4,89E+04	3,26E+04	2,0E+04

Figure 3.3A. Discharges in Bq from Ringhals Unit 3, 1998-2003, for H-3, total alpha and total beta excl. H-3

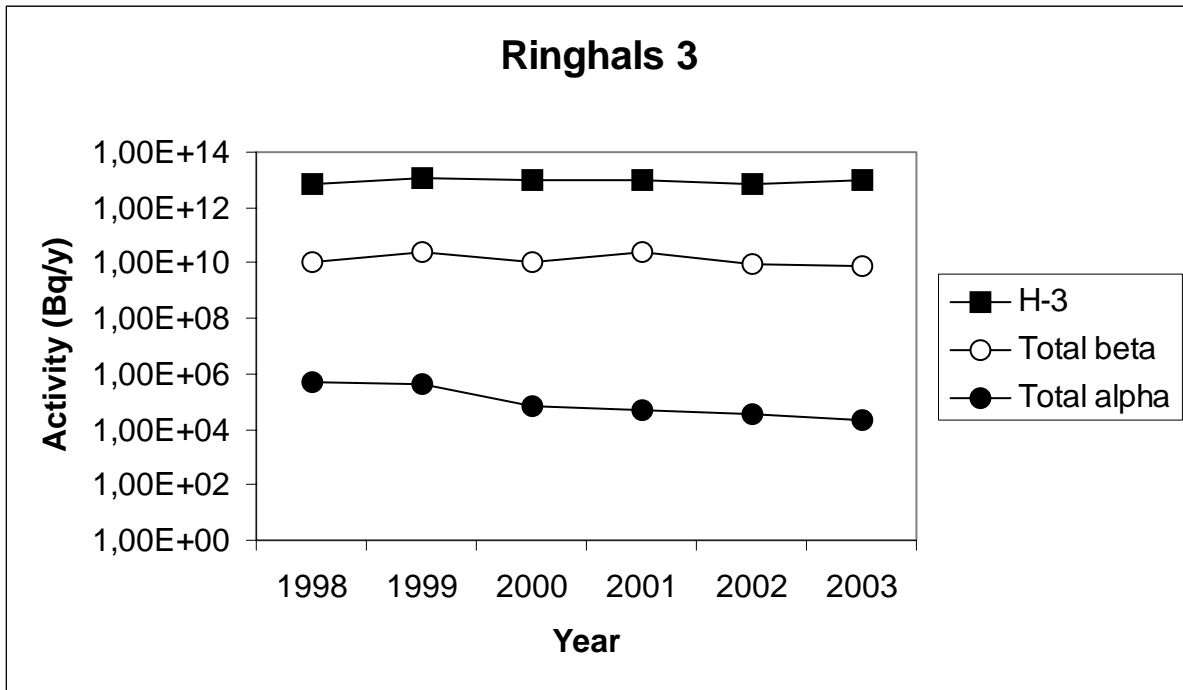


Figure 3.3B. Nuclide specific discharges in Bq from Ringhals Unit 3, 1998-2003

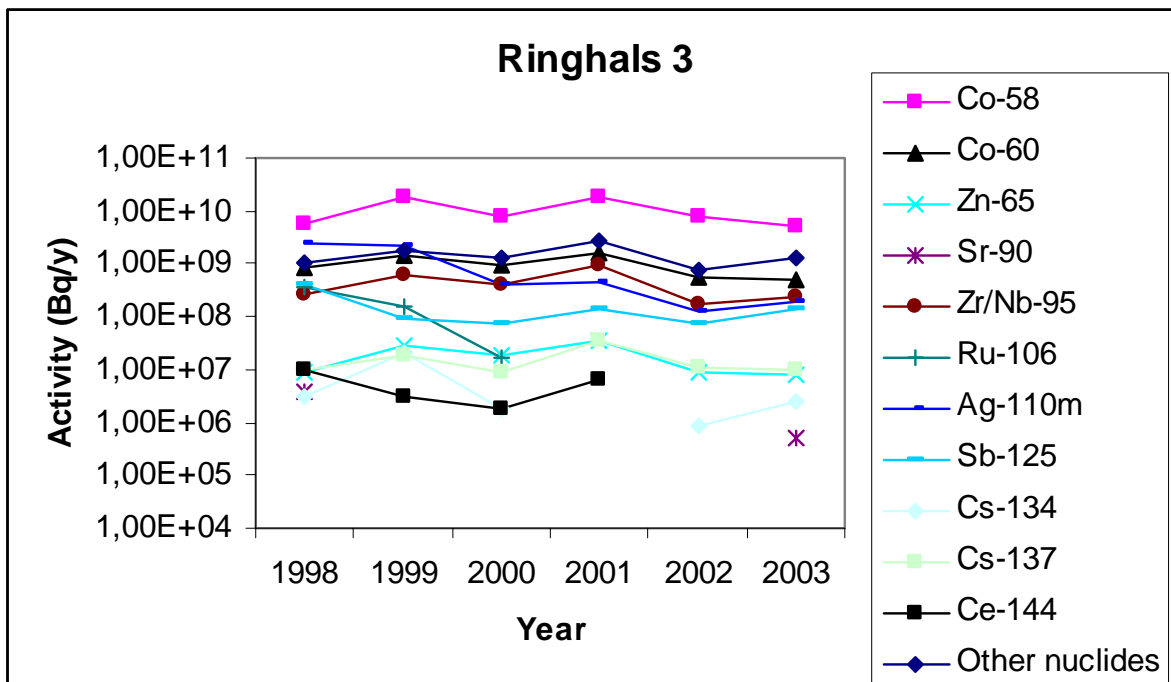


Table 3.10. Discharges in Bq from Ringhals Unit 4, 1998-2003

Nuclide	1998	1999	2000	2001	2002	2003
H-3	1,03E+13	1,42E+13	5,67E+12	4,58E+12	7,73E+12	1,12E+13
Co-58	2,48E+09	9,73E+09	3,17E+09	1,08E+10	2,17E+09	3,46E+08
Co-60	1,08E+09	1,39E+09	7,94E+08	6,81E+08	1,17E+08	1,98E+08
Zn-65	5,78E+06	4,79E+06	8,91E+06	6,26E+06	6,48E+05	6,01E+05
Sr-90	0			2,01E+06	1,48E+05	7,90E+04
Zr/Nb-95	1,28E+08	4,01E+08	3,44E+08	1,62E+08	3,08E+07	7,63E+07
Ru-106	1,10E+07	3,11E+07				
Ag-110m	1,61E+08	1,30E+08	8,01E+07	3,99E+07	4,85E+06	8,02E+05
Sb-125	3,59E+08	6,21E+07	1,49E+08	9,64E+07	1,05E+07	1,66E+07
Cs-134	2,17E+07	3,59E+06		2,08E+07	1,45E+07	4,45E+07
Cs-137	4,30E+07	1,77E+07	8,04E+06	3,16E+07	2,25E+07	7,90E+07
Ce-144		1,47E+06	1,20E+06	4,86E+05		
Other nuclides	5,51E+08	8,85E+08	1,03E+09	6,88E+08	2,00E+08	3,28E+08
Total beta(excl H-3)	4,84E+09	1,27E+10	5,58E+09	1,25E+10	2,57E+09	4,20E+09
Total alpha	6,10E+04	2,59E+04	2,81E+05	3,62E+05	3,66E+04	6,27E+04

Figure 3.4A. Discharges in Bq from Ringhals Unit 4, 1998-2003, for H-3, total alpha and total beta excl. H-3

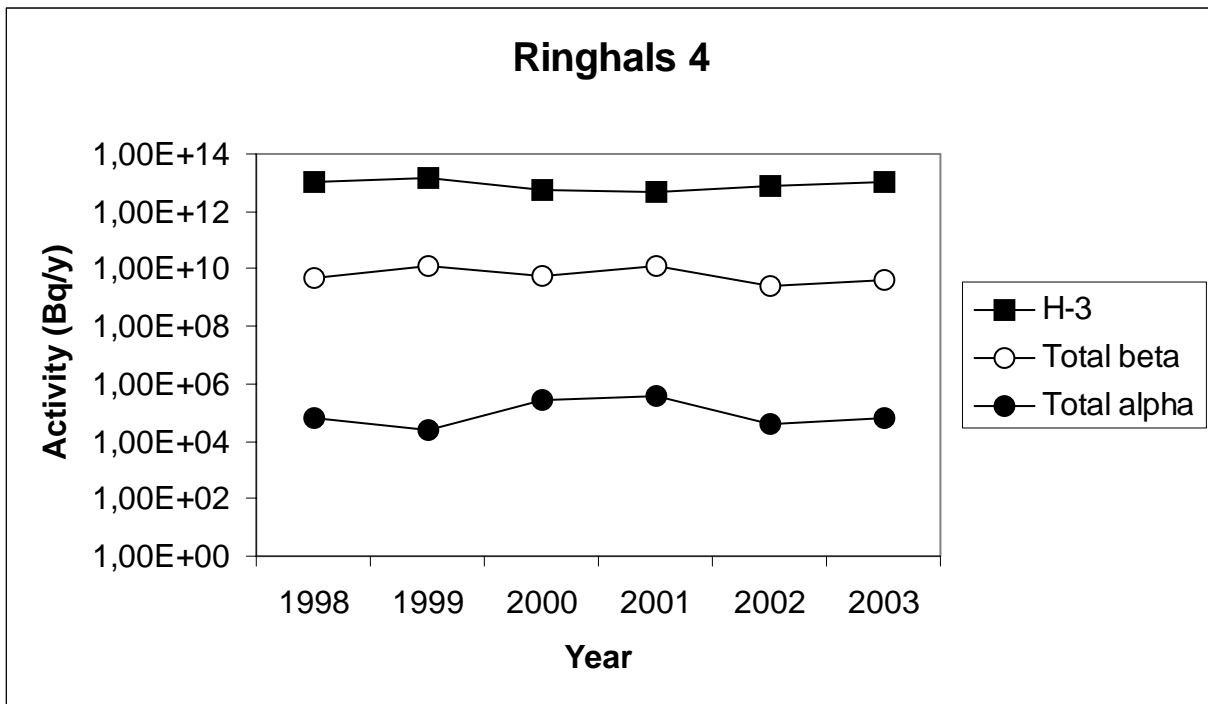
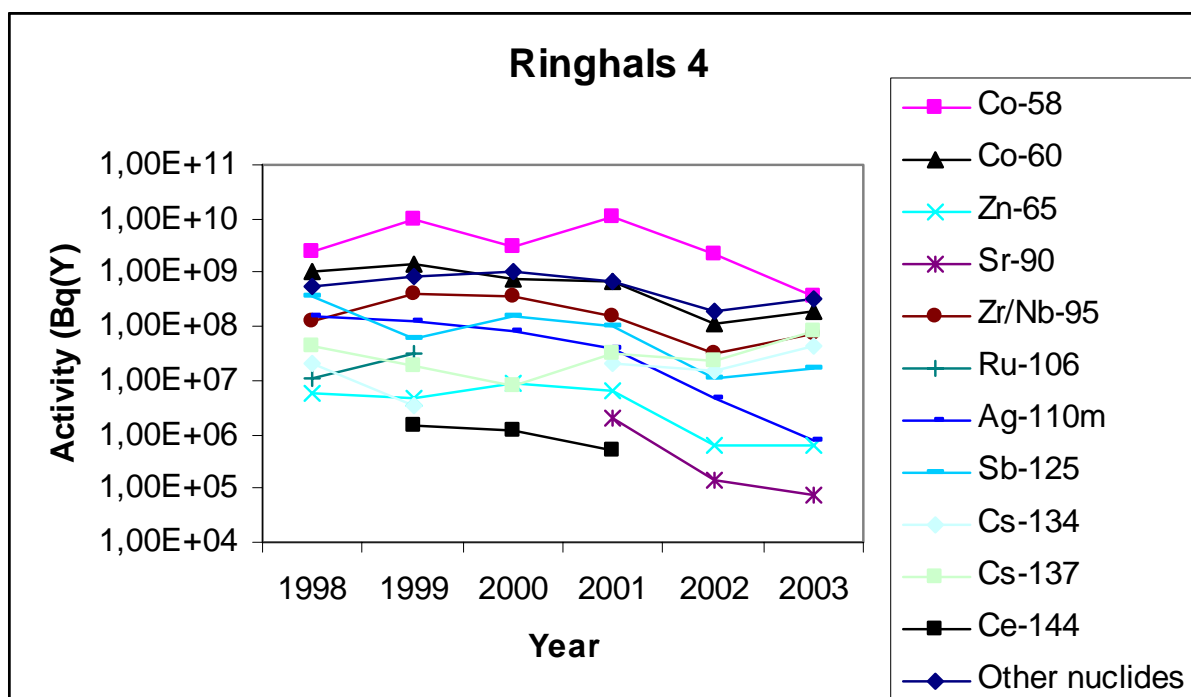


Figure 3.4B. Nuclide specific discharges in Bq from Ringhals Unit 4, 1998-2003



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 compared to 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 3.11. There are no data for calculating normal ranges of normalised alpha emitters in the UNSCEAR report.

It should be noted that the most recent UNSCEAR report published in 2000 only covers data until 1997, i.e. there are no UNSCEAR data available for the years covered by this report, from 1998 and onwards.

Table 3.11. 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
Bolting water reactor, BWR	0,29-2,88	3,6-35,7
Pressurised water reactor, PWR	5,91-59,1	2,6-25,9

For PWR:s the average values for 1995 to 1997 are 18,7 TBq/GWa and 8,2 GBq/GWa for tritium and non-tritium, respectively. For BWR:s, the average values were 0,87 TBq/GWa and 11,3 GBq/GWa for tritium and non-tritium, respectively.

The normalised discharge data for the Ringhals Units 1-4 are shown in Table 3.12 and in Figures 3.4-3.5.

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.

Apart from the outside-range values for Ringhals unit 1 during 1998 and 1999 all other values for Units 1-4 have mainly been in-range during the period covered by this report. The explanation for the outside-range values in 1998-1999 is that the full effect of the cobalt replacement in the systems had not been achieved at

the time. 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.

Normalised data for alpha discharges are given in Table 3.12. The trends are either downwards or constant during the period.

Table 3.12. Normalized discharge data for Ringhals Units 1 – 4 during 1993 – 1998. Data are given in Bq/GWa.

Unit	Nuclide group	1998	1999	2000	2001	2002	2003
Ringhals 1	Alpha	1,72E+07	5,20E+06	8,59E+06	4,74E+06	1,60E+06	1,02E+06
	Total beta excl H-3	8,20E+10	5,16E+10	3,06E+10	2,99E+10	9,82E+09	8,62E+09
	Tritium	8,58E+11	1,73E+12	1,38E+12	1,00E+12	1,08E+12	1,69E+12
Ringhals 2	Alpha	5,17E+06	7,03E+05	1,95E+06	5,08E+05	4,18E+05	5,60E+04
	Total beta excl H-3	3,55E+10	6,29E+09	1,39E+10	1,62E+10	9,05E+09	7,64E+09
	Tritium	1,22E+13	1,89E+13	1,89E+13	1,43E+13	1,14E+13	2,10E+13
Ringhals 3	Alpha	6,69E+05	5,09E+05	9,78E+04	6,72E+04	4,09E+04	2,58E+04
	Total beta excl H-3	1,56E+10	3,04E+10	1,54E+10	3,25E+10	1,20E+10	1,02E+10
	Tritium	9,27E+12	1,40E+13	1,27E+13	1,26E+13	9,06E+12	1,27E+13
Ringhals 4	Alpha	7,85E+04	3,19E+04	6,02E+05	4,73E+05	5,33E+04	7,72E+04
	Total beta excl H-3	6,23E+09	1,57E+10	1,20E+10	1,63E+10	3,75E+09	5,17E+09
	Tritium	1,32E+13	1,75E+13	1,22E+13	5,98E+12	1,13E+13	1,38E+13

Figure 3.4. Normalised discharges from Ringhals Unit 1, 1998-2003, for H-3 and total beta excl. H-3, including ranges according to UNSCEAR 2000.

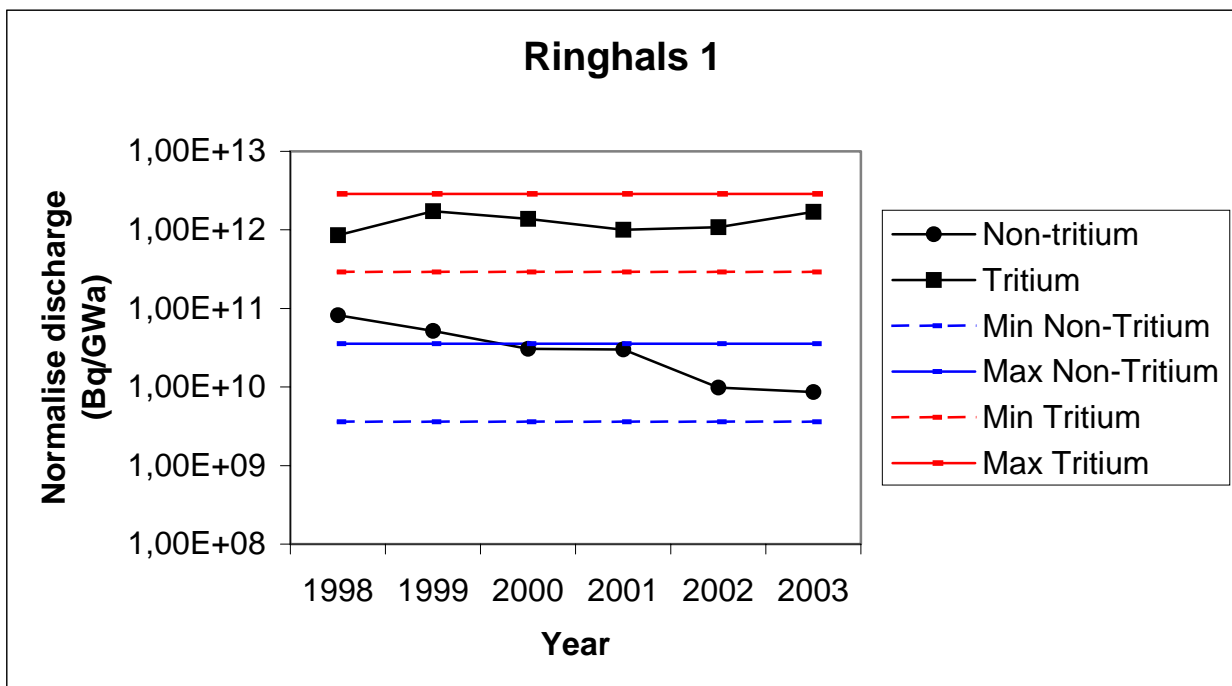
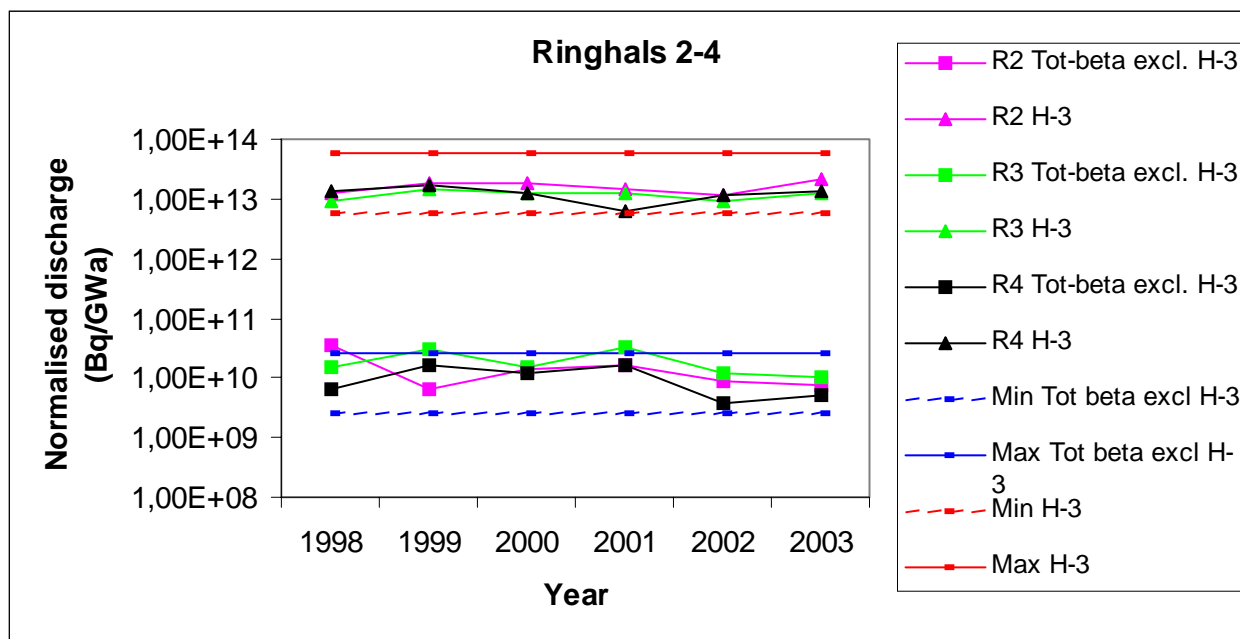


Figure 3.5. Normalised discharges from Ringhals Units 2- 4, 1998-2003, for H-3 and total beta excl. H-3, including ranges according to UNSCEAR 2000.



3.2.5 Emissions to air of concern for the marine environment

Emissions to air of C-14 and H-3 have been measured since 2002 when regulations (SSI FS 2000:12) entered into force. Before 2002, emissions to air of C-14 were estimated based on international experience. Table 3.13 shows the emissions of C-14 and H-3 for 2002 and 2003. Measurements of emissions of I-129 is not requested by the SSI.

Table 3.13. Emissions of carbon-14 and tritium in Bq (both oxidised and reduced chemical forms included)

Unit	Radionuclide	2002	2003
Ringhals 1	Tritium	1,01E+11	1,39E+11
	Carbon-14	4,71E+11	3,81E+11
Ringhals 2	Tritium	1,90E+11	2,67E+11
	Carbon-14	2,65E+11	2,38E+11
Ringhals 3	Tritium	3,55E+11	5,15E+11
	Carbon-14	2,72E+11	2,06E+11
Ringhals 4	Tritium	3,34E+11	4,74E+11
	Carbon-14	2,22E+11	1,14E+11

The data series are too short to evaluate any trends.

3.2.6 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 a higher level of management.

3.2.7 Site-specific target discharge

For nuclear power reactors site-specific target discharge values have been introduced in 2002. These values are called reference values and target values. 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 are considered to be measures of the normal abatement capability of different reactors. The values 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 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 given period of time".

For the reactors at the Ringhals nuclear power station, the reference and target values for discharges chosen for the time period 2002 to 2006 together with the monitored discharges for 2002 and 2003 are shown in Table 3.14.

Table 3.14. Reference and target values for discharges from Ringhals Units 1-4, and the monitored discharges for 2002 and 2003.

Unit	Radionuclide	Reference value (Bq/a)	Discharges 2002 (Bq/a)	Discharges 2003 (Bq/a)	Target value (Bq/a)
R1	Co-60	2,0E+10	3,60E+09	2,20E+09	2,0E+10
	Cs-137	2,0E+09	6,40E+08	5,80E+08	2,0E+09
R2	Co-60	2,5E+09	7,00E+08	2,75E+08	2,5E+09
	Cs-137	2,5E+07	1,00E+07	2,40E+07	2,5E+07
	Sb-124	5,0E+09	2,10E+09	2,75E+09	5,0E+09
R3	Co-60	2,0E+09	5,60E+08	4,80E+08	2,0E+09
	Cs-137	2,5E+07	1,05E+07	9,50E+06	2,5E+07
R4	Co-60	1,5E+09	1,20E+08	1,95E+08	1,5E+09
	Cs-137	2,5E+07	2,25E+07	8,00E+07	2,5E+07

The reasons 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. 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. The target values coincide with the reference values which reflect the fact that no major economic investments are planned during the period to 2006 to reduce the discharges. During the last ten years resources have been spent on reducing the emissions.

Except for Cs-137 discharges from Ringhals 4 in 2003, the discharges are below the reference values. The higher discharge of Cs-137 is due to a fuel leakage in 2003. The damaged fuel was also removed in 2003.

In 2002, the emission reference values for *fission gases and iodine* in Unit 4 were exceeded due to fuel leakages. A minor leakage of fission gases in Unit 2 caused the reference value for Xe-135 to be exceeded. The reference values for Kr-88 and Co-60 in Unit 1 were exceeded due to leakage of air into the turbine system, which lead to shorter delay times in the system.

As a consequence of fuel leakages in Units 3 and 4 (the same that caused the discharges of Cs-137) the emissions to air exceeded the reference values for fission gases and iodine in 2003. Due to maintenance work in Unit 1 the reference value for emissions of Co-60 to air was exceeded.

In total for discharges and emissions, 6 of 30 reference values were exceeded during 2002 and 9 of 30 reference values during 2003.

In spite of the fact that some reference values (mainly for emissions) were exceeded during 2002 and 2003, it is estimated that the emissions and discharges will be below the target values in 2006. This is achieved by:

- preventing fuel damage (clean cores)
- good housekeeping (will lead to lower discharges)
- possibly some improvement of technology
- improved cleaning of water from laundry
- use of less water (BATMAN project).

3.2.8 Other relevant information

There is no other relevant information.

3.2.9 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 recombiner 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. A second stage is being planned, in which significant contributions to volume or activity will be reduced either by modification of the equipment or by using modified operating procedures.

DATA COMPLETENESS AND COMPLIANCE

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

3.2.10 Summary Evaluation

The following Table 3.15 summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on discharges from Ringhals four reactor units.

Table 3.15. Summary Evaluation of Discharges

Criteria	Evaluation
The BAT/BEP indicators	
<ul style="list-style-type: none"> • Relevant systems in place 	Yes, Management and technical systems improved since the start of the reactors, possibly with the exception of the lack of evaporation plant
<ul style="list-style-type: none"> • Abatement factor 	According to what is normal for the existing abatement systems
<ul style="list-style-type: none"> • Downward trend in discharges 	Constant or downwards
<ul style="list-style-type: none"> • Downward trend in normalized discharges 	Mainly constant or downwards
<ul style="list-style-type: none"> • Comparison with UNSCEAR data 	Within the range of available UNSCEAR data
<ul style="list-style-type: none"> • Downward trends in emission 	Too few years of measurements for trend evaluation of C-14 and H-3.
<ul style="list-style-type: none"> • Relevant and reliable quality assurance 	Yes
<ul style="list-style-type: none"> • Relevant site specific discharge values 	Yes
Data completeness	Complete
Causes for deviations from indicators	See text above
Uncertainties	No influence on the conclusions
O	None

3.3 Environmental impact

3.3.1 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 and fish. The fish is represented by eel (*Anguilla anguilla*) and by corkwing (*Crenilabrus melops*). The samples have been taken at stations close to the discharge points, station 3 for sediment and station 22 for the fish samples.

Table 3.16. Radionuclide concentrations in sediments close to the discharge points of the Ringhals nuclear power plant (station 3). Radionuclide concentrations are given in Bq kg⁻¹ dry wt.

Date	Mn-54	Co-58	Co-60	Cs-137	Nb-95
1998-02-13	1	1	11	3	<1
1998-06-02	3	<1	39	4	<1
1998-09-29	1	<1	5	2	<1
1998-12-28	1	<1	24	4	<1
1999-03-31	<1	<1	12	4	<1
1999-06-17	1	1	19	5	<1
1999-09-23	1	3	22	3	<1
1999-12-20	0	<1	6	2	<1
2000-03-30	<1	<1	4	2	<1
2000-06-09	<1	<1	2	2	<1
2000-09-29	<1	1	5	3	1
2000-12-29	<1	1	5	3	1
2001-03-30	<1	<1	4	2	<1
2001-06-25	<1	<1	3	1	<1
2001-09-28	<1	1	6	2	2
2001-12-13	<1	<1	4	2	<1
2002-03-25	<1	<1	2	2	<1
2002-06-24	<1	<1	4	5	<1
2002-09-30	<1	<1	6	6	<1
2002-12-12	<1	1	9	3	<1
2003-03-27	<1	<1	4	3	<1
2003-06-16	<1	1	3	2	1
2003-09-30	1	<1	5	2	<1
2003-12-02	<1	<1	2	2	<1

Table 3.17. Radionuclide concentrations in eel (*Anguilla anguilla*) close to the discharge points of the Ringhals nuclear power plant (station 22). Radionuclide concentrations are given in Bq kg⁻¹ dry wt.

Date	Co-60	Cs-137
1998-04-16	2	8
1998-09-29	1	10
1999-04-07	1	9
1999-10-22	25	363
2000-04-13	<1	11
2000-10-02	2	8
2001-04-10	<1	10
2001-09-28	<1	7
2002-04-17	1	9
2002-09-25	<1	7
2003-05-09	<1	8
2003-09-03	<1	8

Table 3.18. Radionuclide concentrations in corkwing (*Crenilabrus melops*) close to the discharge points of the Ringhals nuclear power plant (station 22). Radionuclide concentrations are given in Bq kg⁻¹ dry wt.

Date	Co-60	Cs-137
1998-04-15	2	17
1998-09-28	2	17
1999-04-08	1	16
1999-10-22	<2	14
2000-04-05	<1	15
2000-10-02	3	15
2001-04-17	<1	16
2001-09-28	<1	13
2002-04-16	<1	14
2002-09-25	<1	14
2003-05-09	<1	12
2003-09-03	<1	11

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, the values given are in dry weight, and there are no detectable trends.

3.3.2 Environmental monitoring programme, frequency of sampling, organisms and or other types of environmental samples considered

The environmental monitoring programme is described in Section 2.4. In particular, the sample types collected and the frequency of collections are given in Tables 2.2 and 2.3. The programme covers biotic and abiotic parts in the aquatic and terrestrial environments.

3.3.3 Systems for quality assurance of environmental monitoring

The SSI environmental monitoring programme describes in detail sampling, sample preparation and measurement and this 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. SSI also checks the environmental analyses through randomly selected sub samples which are being analyzed at independent laboratories.

3.3.4 Other relevant information

There is no other relevant information.

3.3.5 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.

The environmental monitoring programme is presently under revision and the new programme will enter into force 2005.

3.3.6 Summary Evaluation

The following Table 3.19 summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on Environmental Impact from Ringhals four reactor units.

Table 3.19. 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.

3.4 Radiation doses to the public

3.4.1 Average annual effective dose to individuals in the critical group

According to the Swedish regulations (SSI FS 2000:12), the effective dose to an individual in the critical group of 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.

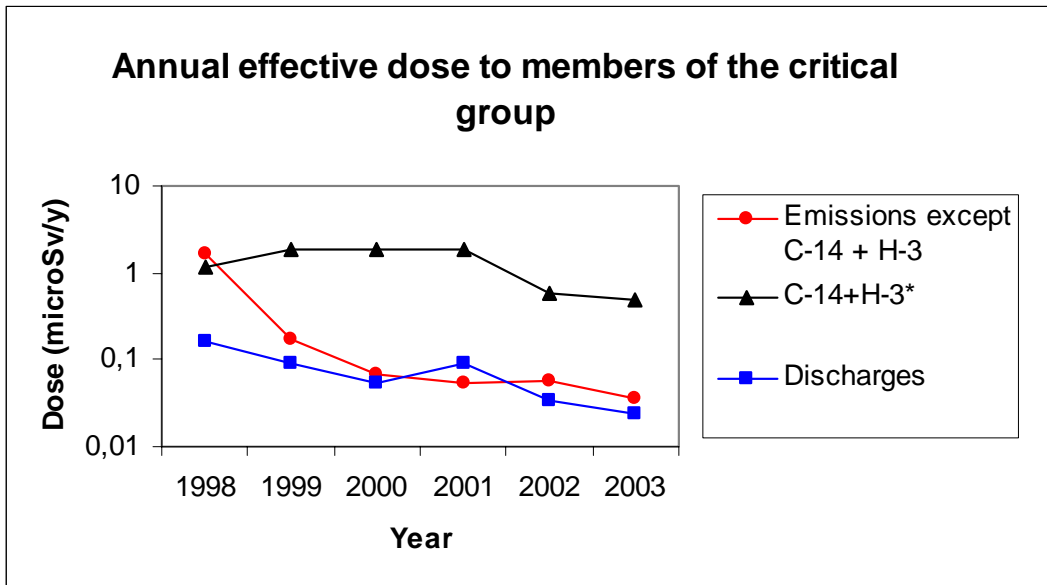
The annual average effective doses to individuals of the critical group from discharges and emissions for the period 1998-2003 are given in Table 3.20 and Figure 3.6.

Table 3.20. Annual effective dose to members of the critical group resulting from emissions and discharges from the Ringhals nuclear power plant (microSv).

Year	1998	1999	2000	2001	2002	2003
Emissions Except C-14 and H-3	1,7	0,17	0,067	0,055	0,056	0,035
Emissions C-14 and H-3*	1,2	1,9	1,9	1,9	0,57	0,48
Discharges	0,16	0,09	0,054	0,090	0,033	0,024

* For 1998-2001, the dose is a theoretical estimate for C-14. For 2002-2003, the dose estimates are based on monitoring the emissions of C-14 and H-3. All results based on the models which were revised 2002.

Figure 3.6. Annual effective dose to members of the critical group around Ringhals



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 the reporting period the two dose contributions are within a factor of two (C-14 not included). There is a decreasing trend in the doses during the six years presented in this report. It should be noted that as a consequence of the revision of the models in 2002 there is a shift towards lower doses in particularly for the doses from C-14. After the revision, the models are more realistic in accordance with the requirements in the EU Directive 96/29/Euratom.

3.4.2 The definition of critical groups

According to the definition in the Swedish regulations (SSI FS 2000:12), 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.

3.4.3 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 has 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.

3.4.4 Basis for methodology to estimate doses

The model² used for calculating dispersion and migration of radioactive substances in the environment and for calculating the radiation doses was revised as a consequence of new regulations entering into force in 2002. The basic compartment model has been tested in international model validation studies.

3.4.5 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 2.3 for more information.

3.4.6 Site-specific target annual effective dose

There is no site-specific target annual effective dose. The same constraint is valid for all nuclear sites, 0,1 mSv/year irrespective of the number of sources within the site.

3.4.7 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 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.

A revision of the essential processes involved in the dose estimates takes place regularly (1977, 1991, 2002).

3.4.8 Any relevant information not covered by the requirements specified above

There is no other relevant information.

3.4.9 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.

3.4.10 Summary Evaluation

The following Table 3.21 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 3.21. Summary Evaluation of Radiation Doses to the Public

Criteria	Evaluation
The BAT/BEP indicators	
• Downward trend in radiation dose	Yes
• 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

² A model developed by Studsvik Eco & Safety.

3.5 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.

4. Site-specific – Barsebäck nuclear power plant

4.1 Site characteristics

4.1.1 Name of site

Barsebäck nuclear power plant is operated by Barsebäck Kraft AB (BKAB)

4.1.2 Type of facility

Nuclear power plant with two boiling water reactors, BWR (ASEA Atom, now Westinghouse Electric Sweden AB). Auxiliary facilities for waste treatment, maintenance, etc.

4.1.3 Start and termination of operations

Table 4.1. Start of operations (criticality and commercial operation) for the Barsebäck reactor units

Unit	Type	Criticality, year	Commercial operation, year	Shut down, year
Barsebäck 1	BWR	1975	1975	1999
Barsebäck 2	BWR	1977	1977	

In accordance with a governmental decision the Barsebäck Unit 1 was permanently terminated on 30 November, 1999. There is also a proposal about the termination of operation of Barsebäck Unit 2 in 2005.

4.1.4 Location

Barsebäck is located in the south of Sweden, approximately 20 km N Malmö and 20 km E Copenhagen (Denmark).

4.1.5 Receiving waters and catchment area

The plant discharges into the Öresund Strait, from a single discharge point immediately at the coast line outside the Convention waters. Air-borne releases are predominantly made through the main stack of each reactor unit, i.e. from two emission points.

4.1.6 Production

The installed electrical effect at the plant is 2 x 615 MW = 1230 MW

Table 4.2. Net electrical output from Barsebäck Units 1 and 2, 1998 – 2003, in GWh

Unit	1998	1999	2000	2001	2002	2003
Barsebäck 1	0,493	0,305	0	0	0	0
Barsebäck 2	0,457	0,402	0,337	0,513	0,447	0,266

4.1.7 Other relevant information

There is no other relevant information

4.2 Discharges

4.2.1 Systems in place to reduce, prevent or eliminate discharges

Information about the systems in place to reduce, prevent or eliminate discharges to the marine environment is shown in Table 4.3. Clean-up of waste water is performed by using ion exchange filters in the reactor cleaning circuit (system 331), ion exchange filters for condensate cleaning, and mechanical and ion exchange filters for separation of particulate and ionogenic contaminants from the waste water in the waste facility. An evaporation plant can be taken into use if a fuel failure occurs.

Systems for clean-up of emissions to air include recombiners and sand tanks for retention of noble gases in the process gases, and carbon/HEPA filters for ventilation of offgases during operation.

During 2001 the waste treatment systems have been extensively modernised. Valves and piping and sampling equipment have been replaced and new switchgear and computer aided control rooms have been installed.

Table 4.3. Barsebäck Units 1 and 2 systems in place to reduce, prevent or eliminate discharges and their efficiency

Abatement system/Management	Into operation (Year)		Efficiency of abatement system
	Existing	Planned	Decontamination Factor
Discharges:			
Cross-flow filtration	1977		1-2
Ion Exchange	1977		2-10
Emissions:			
Delay tanks	1977		15
HEPA filtration	1977		5-10

4.2.2 Efficiency of abatement systems

The efficiency of the abatement systems in place in the Barsebäck reactors are summarised in Table 4.3.

The efficiency of the abatement systems for discharges varies between 2 and 20 depending of the chemical composition of the waste water from the laundry.

4.2.3 Annual liquid discharges

ABSOLUTE DISCHARGES

The discharges have been fairly stable during 1998 to 2003 (see Table 4.4 and Figures 4.1 a and b). In December 1999, Barsebäck Unit 1 was permanently shut down. A fuel failure was detected at the Barsebäck Unit 2 in December 1999. The damaged fuel was replaced during the summer outage period in 2000. This resulted in higher emissions of noble gaseous during the first six month period in 2000. The increase of mainly Co -60 in the discharges during 2000-2003 is partly explained by zinc injection into the reactor cooling system as an effort to reduce the oxide layer. Also during 2000 the last fuel assembly was removed from the B1 reactor and consecutively the Wet well was drained resulting in an increase in waste water volume discharged to the recipient by a factor of two. During 2001 the waste treatment systems have been extensively modernised and this has given rise to an increase of discharges of a variety of radionuclides.

Table 4.4. Discharges in Bq from the Barsebäck nuclear power plant. Units 1* and 2. 1998 - 2003

Nuclide	1998	1999	2000	2001	2002	2003
H-3	4,90E+11	6,90E+11	4,00E+11	3,19E+11	3,02E+11	2,45E+11
Co-58	3,70E+09	3,00E+09	1,90E+09	3,09E+09	4,79E+09	3,79E+09
Co-60	9,20E+09	1,50E+10	1,80E+10	3,07E+10	1,76E+10	9,50E+09
Zn-65	1,70E+08	1,90E+08	2,50E+08	4,09E+08	5,95E+08	4,00E+08
Sr-90	8,75E+05	1,50E+06	8,57E+05	1,59E+06	1,34E+06	5,43E+06
Zr/Nb-95	5,40E+08	2,44E+08	7,8E+07	4,39E+08	3,21E+08	1,56E+09
Ru-106						
Ag-110m	9,50E+07	1,80E+08	1,10E+08	1,68E+08	4,46E+08	1,71E+07
Sb-125	4,20E+08	2,30E+07	7,40E+08	5,62E+08	2,03E+07	4,98E+08
Cs-134	1,90E+07		1,40E+08	1,12E+09	2,03E+08	1,73E+07
Cs-137	1,00E+09	6,10E+08	1,20E+09	6,97E+09	1,22E+09	3,26E+08
Ce-144						
Other nuclides	2,05E+10	7,17E+09	2,26E+09	5,24E+09	1,52E+10	6,49E+09
Total beta excl, H-3	3,56E+10	2,64E+10	2,47E+10	4,87E+10	4,04E+10	2,26E+10
Total alpha	3,06E+04	8,61E+04	4,06E+04	4,42E+04	5,61E+04	2,11E+04

Unit 1 was closed in December 1999

Figure 4.1 a. Discharges in Bq from Barsebäck Units 1 and 2, 1998-2003, for H-3, alpha and total beta excl. H-3

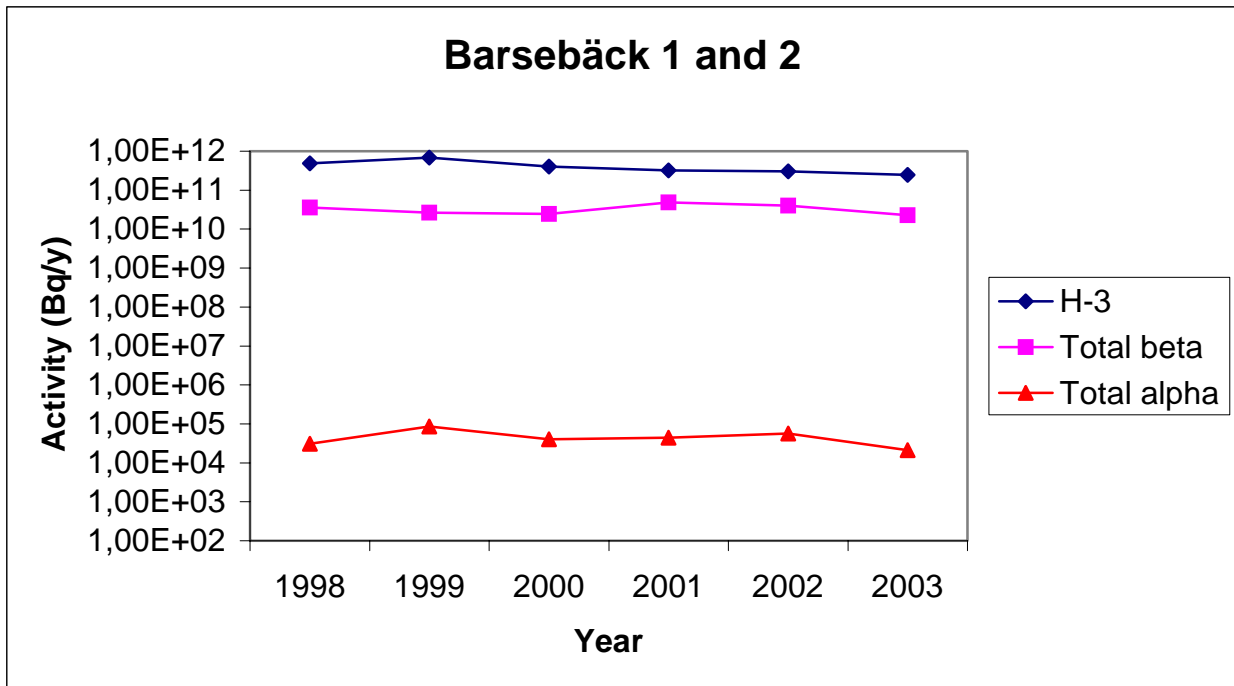
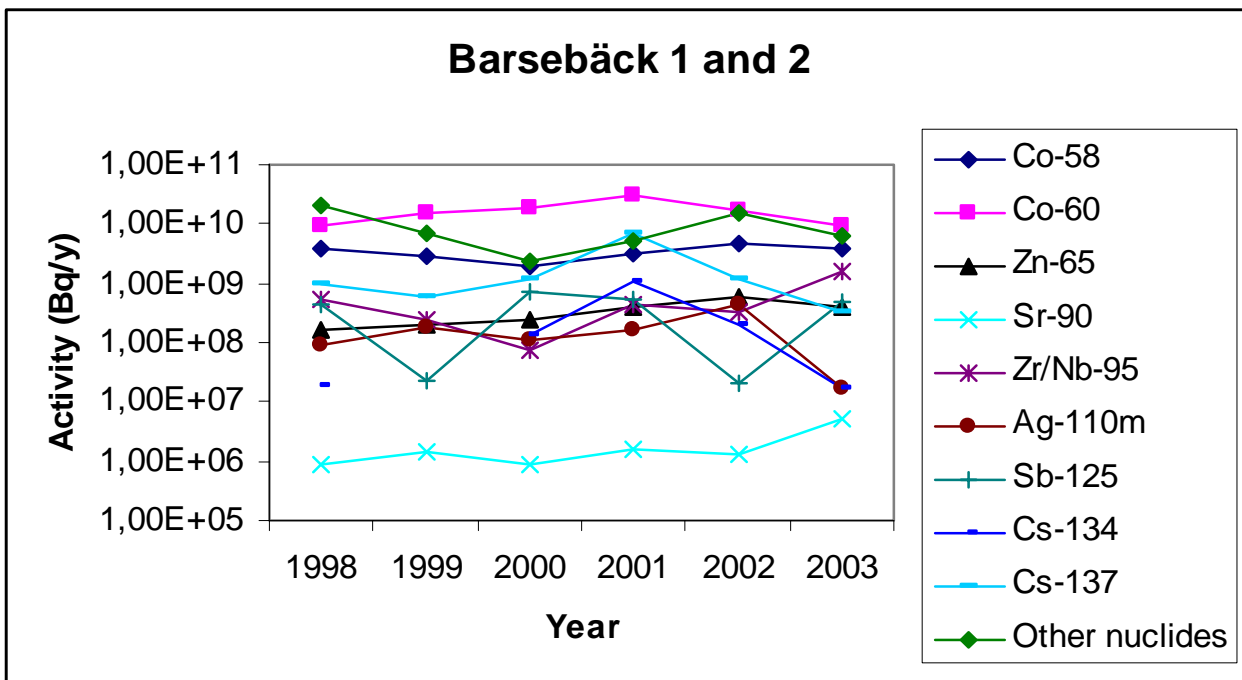


Figure 4.1 b. Nuclide specific discharges in Bq from Barsebäck Units 1 and 2, 1998-2003



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 to 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 4.5. There are no data for calculating normal ranges of normalised alpha emitters in the UNSCEAR report.

It should be noted that the most recent UNSCEAR report published in 2000 only covers data until 1997, i.e. there are no UNSCEAR data available for the years covered by this report, from 1998 and onwards.

Table 4.5. Normalised ranges for annual discharges of beta emitters from BWRs and PWRs, based on UNSCEAR 2000

Reactor type	H-3 TBq/GWa	Beta excl. H-3 GBq/GWa
Boiling water reactor, BWR	0,29-2,88	3,6-35,7

For BWR:s, the average values were 0,87 TBq/GWa and 11,3 GBq/GWa for tritium and other beta-emitters, respectively.

The normalised discharge data for the Barsebäck 1-2 are shown in Table 4.6 and in Figure 4.2. Values "above range" may indicate that BAT is not applied for a specific source, whereas values "within range" or "below range" indicates that BAT may have been applied.

The waste treatment facility is jointly shared between the two units. It is therefore difficult to differentiate the releases from the units. The reason why the releases of radioactive nuclides has not decreased as presumed is probably due to the extended fuel and waste water treatment as a result of the termination of Unit 1. The extended level of Co-60 in the reactor cooling water in unit two is due to zinc injection which was initiated in 1999. Also problems with the particulate filtration system for the waste water have periodically given rise to an increase in the releases of radioactive nuclides to the marine environment. The replacement of valves and pipes in the waste treatment system has also contributed to the increase. In addition the electrical output was lower in 2003 leading to a higher normalised value.

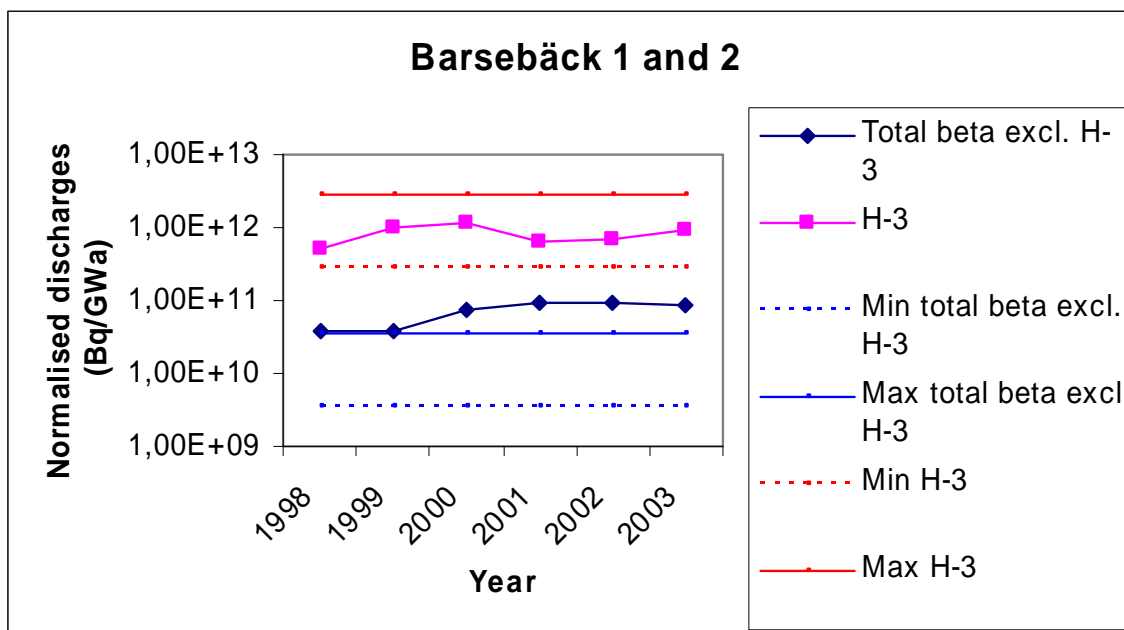
Comparisons can only be made on the basis of long-term performance. Fluctuations between individual years may be large due to long outages (which reduce output but not necessarily discharges), transient phenomena, or irregular discharges.

Table 4.6. Normalised discharges for Barsebäck Units 1 and 2. 1998 - 2003. in Bq per GWa

Nuclide group	1998	1999*	2000	2001	2002	2003
Total alpha	3,01E+04	1,22E+05	1,20E+05	8,62E+04	1,25E+05	7,92E+04
Total beta excl, H-3	3,75E+10	3,73E+10	7,30E+10	9,50E+10	9,03E+10	8,48E+10
H-3	5,16E+11	9,76E+11	1,18E+12	6,22E+11	6,75E+11	9,20E+11

- Barsebäck Unit 1 was permanently shut down in December 1999

Figure 4.2. Normalised discharges from Barsebäck Units 1 and 2, 1998-2003, for H-3 and for other beta emitters, including ranges according to UNSCEAR 2000.



4.2.4 Emissions to air of concern for the marine environment

Emissions to air of C-14 and H-3 have been measured since 2002 when new regulations (SSI FS 2000:12) entered into force. Earlier, emissions to air of C-14 were estimated based on international experience. Table 4.7 shows the emissions of C-14 and H-3 for 2002 and 2003. Measurements of I-129 are not requested by the SSI.

Table 4.7. Emissions of carbon-14 and tritium in Bq. (both oxidised and reduced chemical forms included)

Unit	Radionuclide	2002	2003
Barsebäck 2	Tritium	2,85 E+11	5,87 E+10
	Carbon-14	4,40 E+11	1,59 E+11

The data series are too short to evaluate any trends.

4.2.5 Quality assurance

Noble gases in the exhaust system are analysed weekly and the delay time is calculated from the results.

Clean-up systems: The entire procedure is controlled by instructions. Preventive maintenance is performed with periodical tests. Target control is in use for activity in the clean-up process in the reception tank and the release tank in the waste facility.

Monitoring is performed via on-line conductivity meter, dose rate meter, manual analyses, and measurement of gamma activity for determination of clean-up efficiency. Internal and external quality audits are performed periodically.

4.2.6 Site-specific target discharge values

For nuclear power reactors targeted discharge values have been introduced in 2002. These values are called reference values and target values. 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 are considered to be measures of the normal abatement capability of different reactors. The values 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 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 given period of time".

For the reactors at the Barsebäck nuclear power station, the reference and target values for discharges chosen for the time period 2002 to 2004 together with the monitored discharges for 2002 and 2003 are shown in Table 4.8.

Table 4.8. Reference and target values for discharges from Barsebäck Unit 1 and 2, and the monitored discharges for 2002 and 2003.

Unit	Radionuclide	Reference value (Bq/a)	Discharges 2002 (Bq/a)	Discharges 2003 (Bq/a)	Target value (Bq/a)
B1/B2	Co-60	4,0E+10	1,8E+10	9,5E+9	2,0E+10

The reason why Co-60 has been chosen as reference radionuclide is that Co-60 gives the main contribution to the dose to the critical group and that Co-60 is always detected in the discharges.

4.2.7 Other relevant information

There is no other relevant information.

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

ACTIVITIES

BKAB has a fuel failure strategy which has been adopted by the executive management group.

DATA COMPLETENESS AND COMPLIANCE

Data submitted have been complete in all aspects where the format (which is designed to accommodate for all types of nuclear facilities) is relevant.

4.2.9 Summary Evaluation

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

Table 4.9. Summary Evaluation of Discharges

Criteria	Evaluation
The BAT/BEP indicators	
Relevant systems in place	Systems according to age of reactors and taking into account the plans for termination of operation
Abatement factor	Constant
Downward trend in discharges	Upwards and then constant
Downward trend in normalized discharges	Outside the range of available UNSCEAR data
Comparison with UNSCEAR data	Too few years of measurements for trend evaluation of C-14 and H-3.
Downward trends in emission	
Relevant and reliable quality assurance	Yes
Relevant site specific discharge values	Yes
Data completeness	Yes
Causes for deviations from indicators	See text above.
Uncertainties	About 10 % according to the counting uncertainties.
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 three types of environmental samples from the marine environment, i.e. sediment, eel

(*Anguilla Anguilla*), and plaice (*Platichthys flesus*). The samples have been taken from stations close to the discharge point.

Table 4.10. Radionuclide concentrations in sediments close to the discharge points of the Barsebäck nuclear power plant. Radionuclide concentrations in Bq kg⁻¹ dry wt. Station 38

Date	Mn-54	Co-58	Co-60	Cs-137
1998-03-17	< 0,5	< 0,5	4	47
1998-06-25	< 0,5	< 0,5	9	45
1998-09-18	< 0,5	< 0,5	12	16
1998-12-31	< 0,5	< 0,5	17	43
1999-03-29	< 0,5	< 0,5	3	40
1999-06-28	< 0,5	< 0,5	16	23
1999-10-05	< 0,5	< 0,5	5	35
1999-12-29	< 0,5	< 0,5	< 0,7	43
2000-04-03	< 0,5	< 0,5	15	10
2000-06-23	< 0,5	< 0,5	16	39
2000-10-02	< 0,5	1	11	23
2000-12-28	< 0,5	< 0,5	12	24
2001-03-27	< 0,5	< 0,5	10	32
2001-06-27	< 0,5	< 0,5	11	30
2001-09-27	< 0,5	< 0,5	10	17
2001-12-07	< 0,5	< 0,5	< 0,7	20
2002-03-18	< 0,5	< 0,5	< 0,7	42
2002-06-28	< 0,5	< 0,5	5	35
2002-09-27	< 0,5	< 0,5	9	41
2002-12-10	< 0,5	< 0,5	11	47
2003-04-02	1	< 0,5	4	26
2003-06-17	1	< 0,5	5	27
2003-10-03	< 0,5	< 0,5	< 0,7	7
2004-01-13	< 0,5	< 0,5	4	17

Table 4.11. Radionuclide concentrations in eel (*Anguilla anguilla*) close to the discharge points of the Barsebäck nuclear power plant. Radionuclide concentrations in Bq kg⁻¹ dry wt. Station 7

Date	Co-60	Cs-137
1998-04-28	<0,7	39
1998-10-20	< 0,7	36
1999-05-05	< 0,7	33
1999-10-06	< 0,7	31
2000-05-16	< 0,7	28
2000-10-09	1	22
2001-06-12	1	26
2001-10-01	2	22
2002-04-25	< 0,7	17
2002-09-30	2	19
2003-05-12	2	19

Table 4.12. Radionuclide concentrations in plaice (*Platichthys flesus*) close to the discharge points of the Barsebäck nuclear power plant. Radionuclide concentrations in Bq kg⁻¹ dry wt. Station 18

Date	Co-60	Cs-137
1998-05-28	< 0,7	51
1998-11-03	< 0,7	42
1999-05-03	< 0,7	70
1999-10-04	< 0,7	23
2000-06-05	< 0,7	57
2000-10-03	< 0,7	31
2001-04-10	< 0,7	38
2001-10-14	< 0,7	25
2002-04-23	< 0,7	28
2002-09-24	< 0,7	19
2003-05-22	< 0,7	44
2003-10-08	< 0,7	17

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 are low, the values given are in dry weight, and there are no detectable trends.

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 2.4. In particular, the sample types collected and the frequency of collections are given in Tables 2.2 and 2.3. The programme covers biotic and abiotic parts in the aquatic and terrestrial environments.

4.3.3 Systems for quality assurance of environmental monitoring

The quality assurance of the environmental monitoring programme is described Section 2.4.

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.

The environmental monitoring programme is presently under revision and the new programme will enter into force 2005.

4.3.6 Summary Evaluation

The following Table 4.13 summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on Environmental Impact from Ringhals four reactor units.

Table 4.13. 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	-
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 in a general fashion, present knowledge indicates that the discharges from the Barsebäck 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 (SSI FS 2000:12), the effective dose to an individual in the critical group of 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 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.

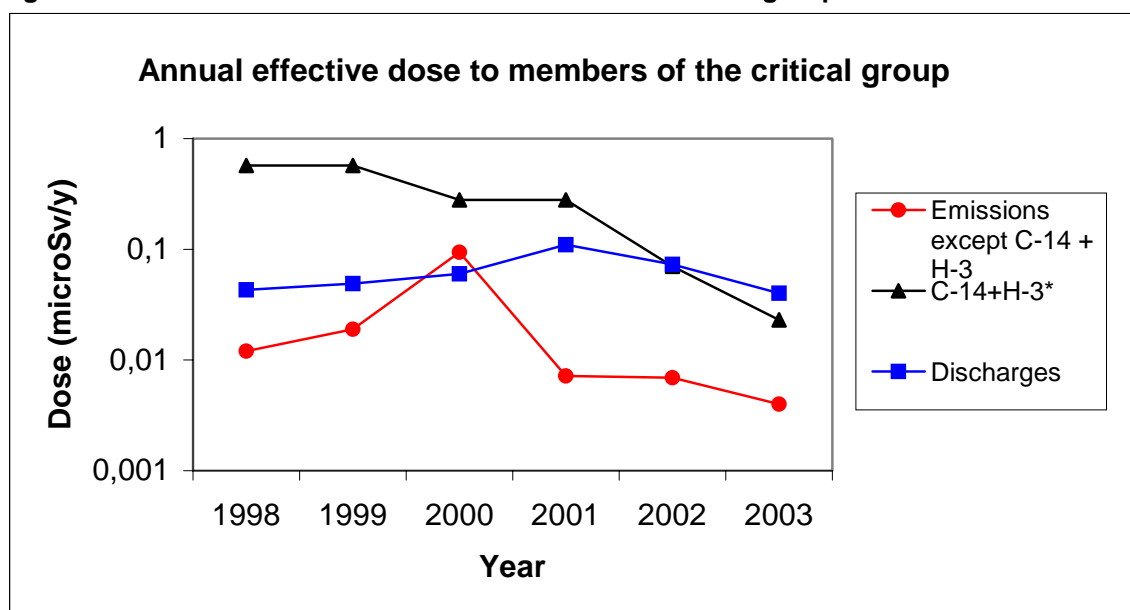
The annual average effective doses to individuals of the critical group from discharges and emissions for the period 1998-2003 are given in Table 4.14 and Figure 4.3.

Table 4.14. Annual effective dose to members of the critical group resulting from emissions and discharges from the Barsebäck nuclear power plant

Year	Annual effective dose (microSv)					
	1998	1999	2000	2001	2002	2003
Emissions excl C-14 and H-3	0,012	0,019	0,094	0,0072	0,0069	0,004
Emissions of C-14 and H-3*	0,57	0,57	0,28	0,28	0,070	0,023
Discharges	0,043	0,049	0,060	0,11	0,073	0,04

*For 1998-2001, the dose is a theoretical estimate for C-14. For 2002-2003, the dose estimates are based on monitoring the emissions of C-14 and H-3. All results based on the models which were revised 2002.

Figure 4.3. Annual effective dose to members of the critical group around Barsebäck



4.4.2 The definition of critical groups

According to the definition in the Swedish regulations (SSI FS 2000:12), 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 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
- 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 has 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.

4.4.4 Basis for methodology to estimate doses

The model³ used for calculating dispersion and migration of radioactive substances in the environment and for calculating the radiation doses was revised as a consequence of new 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 2.3 for more information.

4.4.6 Site-specific target annual effective dose

There is no site-specific target annual effective dose. The same constraint is valid for all nuclear sites, 0,1 mSv/year 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 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.

A revision of the essential processes involved in the dose estimates takes place regularly (1977, 1991, 2002).

Overall, this is included in BKAB's quality system SOL Control and Management Manual chapter 4.9 "Environment". References are the ALARA programme, the Fuel Failure strategy, the Environmental management system, Instructions and internal and external periodic quality audits. Follow-up of target dose, less than 1% of the permitted level to the critical group.

4.4.8 Any relevant information not covered by the requirements specified above

There is no other relevant information.

4.4.9 Explanations 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. Doses are very low, substantially below prescribed levels.

³ A model developed by Studsvik Eco & Safety.

4.4.10 Summary evaluation

The following Table 4.15 summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on Radiation Doses to the Public from the Barsebäck nuclear power plant.

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

Table 4.15. Summary Evaluation of Radiation Doses to the Public

Criteria	Evaluation
The BAT/BEP indicators	
<ul style="list-style-type: none"> • Downward trend in radiation dose 	Yes (doses from discharges are constant and very low)
<ul style="list-style-type: none"> • Relevant critical group 	Yes
<ul style="list-style-type: none"> • Reliable dose estimates 	Yes
<ul style="list-style-type: none"> • Relevance of target dose 	No target dose, but dose constraint for the site
<ul style="list-style-type: none"> • 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

There are low concentrations of radionuclides in the environment surrounding the Barsebäck nuclear power plant and also the radiation doses to the critical group are very low. The absolute discharges are slightly decreasing over the six-year period studied in this report. The interpretation of the normalized discharges is not straightforward. This is partly due to the fact that the liquid waste system in Barsebäck is jointly shared between the two reactor units of which unit 1 is in a decommissioning phase. It is not possible to differentiate between radionuclide contributions from the two waste streams. There are indications that BAT is applied for unit 2 but as there are no criteria for how to apply BAT during decommissioning of unit 1, it is not possible to unambiguously conclude whether BAT is applied or not. It should be noted that the reactor unit 2 will be finally shut down at the end of May 2005.