OSPAR COMMISSION

The Application of Best Available Techniques (BAT) and Best Environmental Practice (BEP) in Nuclear Facilities in Norway

OSPAR Agreement 2018-01

Radioactive Substances Series

2023

The Application of BAT and BEP in Nuclear Facilities in Norway

Referanse

Anvendelsen av BAT og BEP i atomanlegg i Norge DSA-rapport 20XX:nr. Østerås, Direktoratet for strålevern og atomsikkerhet, 20XX.

Emneord

OSPAR, BAT, atomanlegg

Resymé

En rapport om implementering av BAT og BEP i atomanlegg i Norge, for OSPAR Radioactive Substances Committee 2023, med henvisning til OSPAR-avtalen 2018-01

Draft Publisert 2023-01-23
Sider 22

DSA,
Postboks 55,
No-1332 Østerås,
Norge.

Telefon 67 16 25 00
Faks 67 14 74 07
Email dsa@dsa.no
dsa.no

ISSN 2535-7339

Reference

The Application of BAT and BEP in Nuclear Facilities in Norway DSA Report 20XX:no. Østerås: Norwegian Radiation and Nuclear Safety Authority, 20XX.
Language: English

Key words

OSPAR, BAT, nuclear

Abstract

A report on the implementation of BAT and BEP in nuclear installations in Norway, for submission to the OSPAR Radioactive Substances Committee 2023, with reference to OSPAR Agreement 2018-01

Prosjektleder: Carol Robinson

DSA-rapport Nummer [XX] **Publisert** jan 2023

The Application of Best Available Techniques (BAT) and Best Environmental Practice (BEP) in Nuclear Facilities in Norway

OSPAR Agreement 2018-01

Contents

1 Country Profile

1.1 Summary

1.1.1 Relevant national authorities and responsibilities

The Norwegian Radiation and Nuclear Safety Authority (DSA) is the national authority, regulatory body and expert body in matters concerning nuclear safety and security, radiation protection, radiation use, natural radiation, radiation contamination in the environment and radioactive waste management. DSA is responsible for regulating the use of radioactive sources in medicine, manufacturing and research.

DSA is also responsible for regulating the two research reactors and the associated fuel cycle facilities at Halden and Kjeller, and the waste repository in Himdalen. The three facilities are currently run by the Institute of Energy Technology (IFE). IFE is a stated owned research foundation.

The Government has made the decision to take the economic responsibility for decommissioning of the nuclear facilities, and to develop a strategy that involves the development of sufficient disposal capacity to address the increased volumes of waste that will arise from decommissioning. The Government has established a state agency, the Norwegian Nuclear Decommissioning (NND) to be responsible for the management of decommissioning and radioactive waste management form the nuclear sector in the future. NND recently submitted an application for ownership and management of the nuclear facilities in Norway, which is under review by DSA.

DSA is organized as a directorate under the Ministry of Health and Care Services, from which DSA primarily receives funding. DSA is also a directorate under the Ministry of Climate and Environment, with respect to radioactive discharges to the environment and radioactive waste from nuclear and non-nuclear industries, and under the Ministry of Foreign Affairs with respect to implementing safety measures under the Norwegian Government's Action Plan for Nuclear Safety and Security, which sets up long-term goals for cooperation on nuclear safety and security with Russia, Ukraine and other countries in Eurasia (see dsa.no for more information). DSA is also an authority under the Ministry of Defence concerning the regulation of nuclear-powered military vessels entering Norwegian waters and ports. DSA also assists and advises other ministries on matters related to DSA's fields of expertise.

1.1.2 National legislation and basis for regulation

DSA regulates according to three Acts and associated regulations:

- → The Nuclear Energy Activities Act
  - → The Regulation on Nuclear Materials and Facilities
  - → The Regulation on Nuclear Materials etc.
- → The Pollution Control Act
  - → The Regulation on Pollution Control
  - → Regulations relating to the recycling of waste
  - → The Regulation on Radioactive Pollution and Radioactive Waste
- → The Radiation Protection Act
  - → The Regulation on Radiation Protection

The Pollution Control Act has applied to radioactive pollution (including discharges and releases)[1] and radioactive waste since 01.01.2011. Under this Act, pollution is forbidden unless specifically permitted by law, regulations or individual permits. The objective of this Act is to secure a satisfactory environmental quality based on a balance of interests, which includes cost associated with any measures and other economic considerations.

Facilities and activities are also regulated in accordance with the Radiation Protection Act with associated regulations, and in addition nuclear facilities and activities are also regulated by the Nuclear Energy Activities Act and associated regulations.

1.1.3 Application of BAT/BEP in domestic legislation

The Norwegian practice when issuing permits or licences for facilities and activities, is to focus on the application of Best Available Techniques (BAT), the As Low as Reasonably Achievable (ALARA) principle and the precautionary principle. The use of BAT regarding discharge of radioactive substances is implemented under the Pollution Control Act, section 2 3.:

Section 2 Guidelines

> *"The Act shall be implemented in accordance with the following guidelines …*
>
> *3. Efforts to avoid and limit pollution and waste problems shall be based on the technology that will give the best result in the light of an overall evaluation of current and future use of the environment and economic considerations."*

1.1.4 Dose limit, constraints, and discharge limit setting rationale

The dose limit for members of the public and non-occupationally exposed workers from ionizing radiation, specified in the Regulation on Radiation Protection, is an effective dose of 1 mSv/year. The Regulation on Radiation Protection also specifies an effective dose constraint of 0.25 mSv/year.

DSA defines radionuclide-specific discharge limits for each facility and activity. The limits are based on the ALARA principle, historical discharge data and planned changes of facility and activity, while ensuring compliance with the dose limits. The discharge limits are the annual activity level in discharge to water and air.

The operators of facilities and activities must also ensure that the dose constraint, and the dose limits, are not exceeded for the sum of all discharges at a given site.

The permits issued by DSA under the Pollution Control Act are issued to IFE for their activities on the Kjeller site and Halden site, and do not differentiate between the different types of facilities i.e. fuel fabrication facility, radioactive waste treatment facility or

[1] The definition of pollution according to the Pollution Control Act § 6.
For the purpose of this Act, pollution means:

1. The introduction of solids, liquids or gases to air, water or ground,
2. Noise and vibrations,
3. Light and other radiation to the extent decided by the pollution control authority
4. Effects on temperature

Which causes or may cause damage or nuisance to the environment,

The term pollution also means anything that may aggravate the damage or nuisance caused by earlier pollution, or that together with environmental impacts such as are mentioned in items 1 to 4 causes or may causes damage or nuisance to the environment.

research reactors. The discharges generated at the site are regulated according to the Pollution Control Act and the Regulation on Radioactive Pollution and Radioactive Waste.

1.1.5 Regulation, surveillance and monitoring

The Norwegian nuclear facilities and activities are inspected by DSA on a regular basis with regard to nuclear safety and security, radiation protection and environmental protection. A part of the inspection is the assessment of the annual reports from facilities and activities on environmental monitoring and routine measurements of discharges of radioactive substances to the environment.

1.1.6 Environmental monitoring programmes

Permits issued by DSA according to the Pollution Control Act require that IFE, the operator of nuclear facilities and related activities, carries out measurements of the discharges to the environmental media water and air. The measurements are conducted according to a monitoring program approved by DSA and the results of the monitoring program are annually reported to DSA.

In addition to the environmental monitoring programs carried out by the operators of facilities and activities, DSA coordinates a national monitoring program of radioactivity present in the marine and terrestrial environments.

The marine monitoring program was established in 1999. The principal objective of the monitoring program is to document levels, distributions, and trends of anthropogenic and naturally occurring radionuclides along the Norwegian coast, in the North Sea, the

Norwegian Sea and in the Barents Sea, and to make information regarding radioactive contamination available to authorities, the fishing industry, media and the public in general.

1.1.7 Radiation dose assessment methods

The total annual effective doses to the public are evaluated from discharges to rivers and from emissions are based on model calculations. The total doses are estimated to the representative person (or hypothetical critical group) from liquid discharges and emissions to the atmosphere for comparison with dose constraints.

Dose rates to non-human biota are also assessed, notably using the ERICA Tool for comparison with associated screening levels and international recommendations.

1.1.8 Environmental norms and standards

Discharge limits are primary based on the assessment of doses to the public and through the application of dose constraints and limits. However, assessments of dose rates to non-human biota are also undertaken, for example using the ERICA Tool.

Reference levels for the activity concentrations of Cs-134 and Cs-137 in foods have also been specified for activity present in the environment as a consequence of the Chernobyl accident.

1.1.9 Quality assurance

The IFE Health and Safety Department has established a quality control and assurance system related to all work tasks, which is described in associated working instructions and procedures. The department is also a member of the International Atomic Energy Agency (IAEA) ALMERA network of radioanalytical laboratories for analysis of environmental samples.

In 2011, IFE was certified to the ISO 9001 and ISO 14001 standards, and re-certified in 2018. Whereas the ISO 9001 involves standard for quality management systems, the ISO 14001 is a standard for environmental management.

1.2 Nuclear Power Plants

N/A

1.3 Reprocessing facilities

N/A

1.4 Fuel fabrication facilities

There are two laboratory-scale fuel fabrication facilities under the management of the Institute for Energy Technology (IFE), located in Kjeller, about 20 km north-east of Oslo. There is also a second nuclear facility located in Halden, about 120 km south of Oslo. Both of these facilities are currently licensed until 31 December 2028.

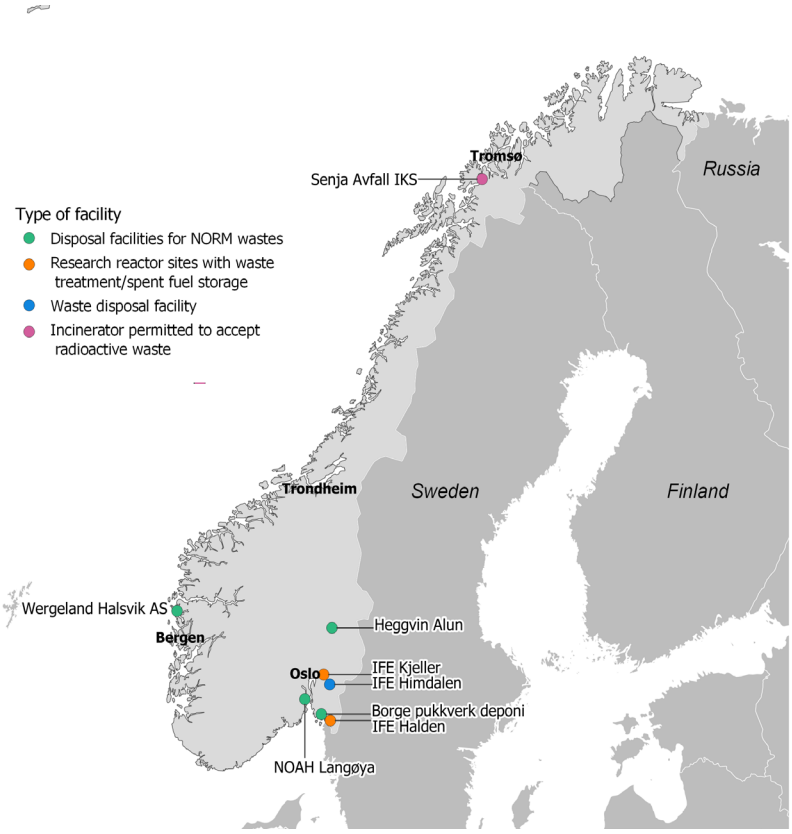

Figure 1: Map of Norway showing location and types of nuclear and radioactive waste management facilities (incl. NORM disposal facilities in green, which are outside the scope of this report).

1.4.1 Facilities at Kjeller:

→ Metallurgisk laboratorium I
was commissioned in 1961, with additions commissioned in 1979 and 1987

→ Metallurgisk laboratorium II
was commissioned in 1965

All liquid effluents from the Kjeller site are pumped to IFE's on site Radioactive Waste Treatment Plant. After treatment these effluents are discharged to the river Nitelva, which is about 100 km from the sea. The river has an annual mean flow of 5 m^3/s. It leads into the lake Øyeren where the water is mixed with the water from the river Glomma, which has an annual mean flow of 400 m^3/s. Glomma river flows into the Oslo Fjord, which has an open connection with Skagerrak (OSPAR region II).

1.4.2 The facility at Halden:

- Brenselsinstrumentverkstedet
was commissioned in 2007

Liquid discharges from the Halden site are released to the river Tista which flows into the Iddefjord leading to Skagerrak (OSPAR region II). The average flow of the river Tista is 21 m^3/s. The volume of the Iddefjord is 4 10^8 m^3, the average outflow to Skagerrak is 180 m^3/s and average inflow from Skagerrak is 150 m^3/s.

1.5 Radioactive waste treatment facilities

The Radioactive Waste Treatment Plant (Radavfallsanlegget) for low level- and intermediate level waste is located at the IFE site in Kjeller. It was commissioned in 1958, with additions commissioned in 1959 and 1966, and is currently licensed until 31 December 2028.

1.6 Research reactors

- → JEEP I (Joint Established Experimental Pile):
  is located at the IFE site in Kjeller. It was commissioned in 1951 and was permanently shut down in 1967 and partially decommissioned.
- → Halden Boiling Water Reactor (HBWR):
  is a 25 MW reactor and part of the OECD Halden project, located at the IFE site in Halden. It was commissioned in 1959. Among other things, it was used for material science research and investigations of high burn-up fuel performance. It was permanently shut down in 2018. Some fuel has been removed. Some fuel and heavy water remain in the reactor vessel, pending defuelling activities.
- → NORA (Norwegian zero effect Reactor Assembly)
  is located at the IFE site in Kjeller. It was commissioned in 1961, as joint Norwegian-IAEA project. It was permanently shut down in 1968 and partially decommissioned.
- → JEEP II
  isa 2 MW heavy water pool reactor, located at the IFE site in Kjeller. It was commissioned in 1967. Its applications included production of isotopes, neutron transmutation doping of silicon and neutron physics research. It was permanently shut down in 2019. All fuel and heavy water have been removed from the JEEP II reactor.

1.7 Decommissioning activities

N/A

No nuclear facilities are in the process of being decommissioned in Norway. Following the decision to permanently shut down the last two operating research reactors in Norway, planning and preparation for decommissioning has intensified.

As indicated above, the research reactors HBWR and JEEP II were permanently shut down in 2018 and 2019, respectively. HBWR and JEEP II, and all related support facilities, will become subject to decommissioning once final decommissioning plans have been developed by the licensee and authorized by the regulator. Decommissioning will also include completing the decommissioning of the remaining parts of the historical research reactors JEEP I and N0RA, which were shut down and put into a safe condition in the 1960s, but not completely decommissioned according to today's standards and requirements. Although decommissioned according to the standards and requirements of the time of shutdown, parts of the reactors remain.

2 Site-specific information

2.1 Institute of Energy Technology, Kjeller

2.1.1 Types of facilities

a) Research reactor JEEP II, heavy water cooled and moderated (shut down).

b) Metallurgic Laboratory I and II, including hot cells.

c) Fuel storage areas.

d) Radioactive Waste Treatment Plant for low and intermediate level waste.

e) Medical Radioactive Isotope Facility

2.1.2 Activities from which liquid effluents arise

The Radioactive Waste Treatment Plant receives and manages radioactive low-level and intermediate-level waste from Norwegian industry, universities, hospitals, and other research institutes as well as from IFE's own facilities. The annual management of solid waste is about 160 drums (210 litres). The drums are transported from IFE Kjeller to the combined storage and disposal facility in Himdalen, 26 km from the Kjeller site.

The Himdalen facility is built into a hillside in crystalline bedrock and consists of 4 caverns (halls) for the storage and disposal of radioactive waste.

Liquid radioactive waste is stored for decay at the production sites or in the Radioactive Waste Treatment Plant. Liquid organic waste is solidified. All radioactive wastewater is pumped to the Radioactive Waste Treatment Plant prior to discharge.

2.1.3 Systems in place to reduce, prevent or eliminate liquid discharges

The discharge limits are specified in the permits issued by DSA according to the Pollution Control Act. The discharge limits are nuclide specific and based on normal activity levels in the effluent water. The discharge shall not result in an annual dose exceeding 1 µSv to the representative person (or members of the critical group) in the vicinity of the river Nitelva.

Low-level liquid radioactive wastes are retained in tanks at the production facilities before being transferred to the Radioactive Waste Treatment Plant for further treatment by evaporation, filtration in ion exchange systems, or retention in large storage tanks for decay. If sufficient tank capacity is available, short-lived radionuclides are normally allowed to decay to a very low level before being discharged.

Relevant systems in place are:

→ Storage to reduce the level of radioactivity of short-lived nuclides

→ Ion exchange filtration

→ Vacuum evaporation system

Discharges are approved on the basis of measurements of the activity levels of gamma emitting radionuclides and tritium provided that the levels of activity are below specific levels. If gamma and tritium results indicate higher levels than normal, the wastewater is retained until all analyses are completed. Otherwise, long lived alpha and beta emitting radionuclides, such as ^{90}Sr, uranium-, plutonium-, americium- and curium isotopes, are evaluated after the discharge. This can be justified by knowledge of the processes generating the waste combined with knowledge of the normal activity levels of these radionuclides.

No new systems have been taken into operation during the reporting period. The discharge permits of radioactive substances includes the obligation to limit the discharge to levels as low as reasonable achievable (ALARA) and to use best available technology (BAT). Equipment, methods, and routines are continuously assessed against possible discharge reduction measures. Since the current discharge levels and resulting doses to the public are very low, see Table 1, large-scale investment in new equipment is unlikely to be warranted and the best results are often achieved through apparently modest changes to existing equipment or procedures, and in increased worker awareness.

Discharges to the river Nitelva are performed according to a control routine to ensure that there is no leakage of wastewater in the pipeline. This routine is applied by flushing clean water through the pipeline before discharge and measuring the water volume at both ends of the pipeline.

Efficiency of abatement systems
No changes to the abatement systems have been introduced during the last six years. Table 1 summarizes the estimated decontamination factors and efficiencies of the abatement systems, as presented in the previous report.

Table 1 Estimated Efficiency of Abatement Systems for Liquid Discharges at IFE-Kjeller

Abatement system	Efficiency of abatement system	
	Decontamination factor	Percentage efficiency (%)
Delay tanks	3	67
Ion exchange[1]	33	97
Vacuum evaporation[1]	20	95

[1]Excluding tritium

2.1.4 Annual liquid discharges

As indicated in Table 2, the discharges are low. The research reactor was shut down in 2019. It is unlikely that major investments would be justified to reduce discharges, and corresponding doses to the representative person further. Variations in liquid discharges are caused by variation in the research activities and production of radiopharmaceuticals and other radionuclides at IFE Kjeller. The operator, IFE, is planning to submit applications for permits for its ongoing activities during 2023.

Table 2 Annual liquid discharges from IFE-Kjeller, 2016 - 2021

Radionuclide	Annual liquid discharge (MBq)					
	2016	2017	2018	2019	2020	2021
H-3	1052	32	3693	81	96000	134
Sr-90	0.0235	0.0097	0.38	0.0028	0.53	0.0022
Cs-134			1.2	0	0.010	0
Cs-137	0.025	0.025	15.9	0.012	1.7	0.023
Co-60	0.077	0.0122	0.84	0.012	0.10	0.032
Pu-238	0.00274	0.00043	0.0016	0	0	0
Pu-239	0.319	0.0108	0.042	0.00042	0.0033	0.0016
Pu-240	0,017	0.00057	0.0022	0.00002	0.00017	0.0009
Am-241	0.0046	0.00095	0.0047	0.000071	0.00063	0.004
Ag-110m			0.078	0	0.011	0
U-234	0.0056	0.00101	0.0088	0.000045	0.0037	0.005
U-235	0.00015	0.00004	0.00035	0	0.00010	0
U-238	0.0056	0.0084	0.0075	0.000043	0.0031	0.005
Cm-244	0.00062	0.000095	0.00074	0	0.000067	0
Ba-133			0.14	0	0.12	0
Ra-223	1.8	0.148	0.021	0.0019	0.0012	0
Th-227	0.056	0.0024	0.050	0.006	0.0033	0

2.1.5 Emissions to air

DSA has issued permits for nuclide specific discharge limits for emissions to the air. In addition, the discharge is limited to an annual dose of 100 µSv to the representative person (or critical group) in the proximity of the IFE site. Additional restrictions on the emission of iodine isotopes apply in the form of a limit to an annual dose of 10 µSv to the same representative person.

Filtration systems with HEPA filters are installed in the ventilation systems from hot cells, fume cupboards and other installations where work with radioactive materials can result in emissions of radioactive aerosols. In the ventilation system from production cells and facilities, where volatile radioactive materials are used, active charcoal filters are installed and in use. HEPA filtration and active charcoal filters are estimated to be 98% and 95% efficient in removing activity, respectively.

Emissions of radioactivity though the filters are continuously monitored. Filters are replaced if measurements show a reduced efficiency.

During operation of the JEEP II research reactor, the main emissions to air were ^{3}H and ^{41}Ar. Small discharges of other radionuclides, notably ^{82}Br, ^{85}Kr and ^{131}I, arise from other activities.

Table 3 Annual emissions to air from IFE-Kjeller, 2016 - 2021

Radionuclide	Annual emissions to air (GBq)					
	2016	2017	2018	2019	2020	2021
H-3	5138	6066	4690	860	314	290
Ar-41	13615	16067	12428	0	0	0
Br-82	0.00096	0.052	0.0113	0	0	0
Kr-85	90.7	16.9	31	7.3	0.71	0
I-131	0.0067	0.0467	0.0115	0.011	0	0

Emissions are low and, before 2019, were primarily associated with the operation of the JEEP II reactor. The trends in the emission of other radionuclides is dependent on other research activities or waste treatment activities.

2.1.6 Environmental Impact

The environmental monitoring program for Nitelva river is conducted by IFE, including the following samples from river water, sediments, fish and water plants:

- → Water samples: three times a year at 6 locations in the river;
- → Sediments: once a year at 6 locations in the river;
- → Water plants: collected twice a year at one location in the river;
- → Fish: fishing of species used for consumption during the summer period.

The radioactivity content is analysed in the laboratories of the IFE Health and Safety Department and reported yearly to DSA.

In 2018, the IFE Health and Safety Department was re-certified to the ISO 9001 and ISO 14001 standards. The department is a member of the International Atomic Energy Agency (IAEA) ALMERA network of radioanalytical laboratories for analysis of environmental samples.

Concentrations of radionuclides in representative samples of water, sediment, and fish
Table 4 shows the average concentration in mBq/l of radionuclides in representative samples of water from three locations in the Nitelva river during the last six years. VA 1 is upstream form the discharge point, VA 4 and VA 5 are downstream form the discharge point. VA 5 is further down than VA 4.

Table 4 Average concentrations of radionuclides in representative samples of water from three locations in the Nitelva river (mBq/L)[2].

Year	Location VA 1 (upstream)		Location VA 4 (downstream)		Location VA 5 (downstream)	
	^{90}Sr	$^{239,240}Pu$	^{90}Sr	$^{239,240}Pu$	^{90}Sr	$^{239,240}Pu$
2016	5,3 (3)	- (0)	3,9 (3)	- (0)	5,6 (3)	- (0)
2017	2,7 (3)	- (0)	3,9 (3)	- (0)	3,9 (3)	- (0)
2018	3.4 (3)	- (0)	3,5 (3)	- (0)	3,6 (3)	- (0)
2019	4.8 (3)	- (0)	5,2 (3)	- (0)	5.9 (3)	- (0)
2020	5.1 (3)	- (0)	4.3 (3)	- (0)	3.8 (3)	- (0)
2021	5.3 (3)	- (0)	9.2 (3)	- (0)	4.1 (3)	- (0)

[2]The numbers in parentheses are the number of samples exceeding the detection limit.

Table 5 shows the activity concentration of radionuclides in samples of sediments (Bq/kg) during the last six years taken at the same locations as the water samples above (SD stands for "sediments"). The results are for the top 10 cm of sediments for annealed samples. The weight ratio between annealed and dried samples are 0.95.

Table 5 Average concentrations of radionuclides in representative samples of annealed sediments from three locations in the Nitelva river (Bq/kg)[2], from top 10 cm

	^{137}Cs	$^{239,240}Pu$	U_{nat}	^{90}Sr
SD 1 (upstream)				
2016	11,3 ± 1,2	0,12 ± 0,04	31 ± 6	0,86 ± 0,28
2017	5,2 ± 0,9	≤ 0,09	35 ± 6	0,94 ± 0,30
2018	2,1 ± 0,8	≤ 0,10	40 ± 4	0,5 ± 0,4
2019	28,5 ± 2,2	≤ 0,17	63 ± 6	1,6 ± 0,5
2020	0.46 ± 0,23	≤ 0,4	34 ± 6	0.4 ± 0.4
2021	1,86 ± 0,29	≤ 0,12	38 ± 7	≤ 0,7
SD 4 (downstream)				
2016	74 ± 5	15,9 ± 2,3	63 ± 12	1,5 ± 0,4
2017	3,0 ± 0,7	1,17 ± 0,23	37 ± 9	0,7 ± 0,4
2018	70 ± 4	340 ± 40	48 ± 5	1,6 ± 0,7
2019[2]	2,2 ± 0,5	≤ 1,7[2]	22,2 ± 2,5	1,2 ± 0,7

[2] Results from extended monitoring around the old emission point (SD4) in point 8. Observed activity level of plutonium isotopes for 0-10 cm layer samples in 15 measurement points is between 23 and 5,300 Bq/kg annealed weight.

	^{137}Cs	$^{239,240}Pu$	U_{nat}	^{90}Sr
2020[3]	28,3 ± 2,4	27 ± 5[3]	47 ± 9	1,1 ± 0,4
2021	80 ± 6	59 ± 11	12 ± 4	0,8 ± 0,5
SD 5 (downstream)				
2016	19,7 ± 1,2	4,1 ± 0,8	39 ± 10	1,4 ± 0,4
2017	15,9 ± 1,1	2,0 ± 0,5	44 ± 11	1,20 ± 0,28
2018	19.6 ± 1.2	4,6 ± 0.8	44 ± 6	1.4 ± 0.7
2019	32 ± 4	3,4 ± 1,5	38 ± 5	0,8 ± 0,5
2020	22,1 ± 1,8	12,5 ± 1,9	36 ± 8	0.7 ± 0.4
2021	31.1 ± 2.2	35 ± 4	45 ± 11	0.9 ± 0.5

Table 6 Concentrations of radionuclides in fish of all types (Bq/kg wet weight)

Year*	^{137}Cs **	$^{239,240}Pu$ **	^{90}Sr
2016 (3)	1,52 ± 0,15	0,0029 ± 0,0018 (2)	0,84 ± 0,07
2017 (2)	2,17 ± 0,22 (1)	- (0)	0,15 ± 0,07
2018	1.6 ± 2.1 (2)	- (0)	0,08 ± 0,09
2019	1,5 ± 1,4 (3)	- (0)	0,06 ± 0,12
2020	1,2 ± 1,6 (2)	- (0)	0,2 ± 0,5
2021	1.2 ± 1.1(3)	- (0)	0.10 ± 0.07

*The total number of samples is given in parenthesis

**The numbers in parenthesis are the number of samples where the radionuclide was measured.

The data from the analyses of water samples, sediments and fish generally show very low values and can therefore be considered to meet BAT/BEP indicators.

The result for the sediments at locations 4 and 5 can be traced to discharges in the 1960s and 1970s and are residues after clean-up of sediments in the riverbed in 2000-2001.

2.1.7 Radiation Doses to the Public

Average annual effective dose to the representative persons from liquid discharges and emissions from IFE Kjeller are given in Table 7.

Table 7 Average annual effective doses to representative persons from IFE Kjeller

[3] Results from extended monitoring around the old emission point (SD4) in point 5. Observed activity level of plutonium isotopes for 12 samples from different measuring points around the SD4 area (between 27 and 1,410 Bq/kg annealed weight

	Annual dose to the representative person (µSv)					
	2016	2017	2018	2019	2020	2021
Liquid discharges	0.00018	0.00008	0.051	0.000035	0.0032	0,000068
Emissions to atmosphere	1.67	1.99	1.52	0.10	0.044	0.065

These are hypothetical assessments, based on modelling assessments. The representative persons do not comprise similar individuals; the doses are therefore not additive.

The representative person for liquid discharges is hypothetical and defined by their food consumption and living habits, summarized as follows:

→ Annual consumption of 20 kg of fish from the river;

→ 100 hours/year occupancy on the riverbank;

→ Bathing and boating give negligible contribution to the doses.

The IAEA Safety Reports Series 19[4] approach was used to estimate doses from theoretical radionuclide concentrations in the local river environment, situated 100 km from the sea, and calculated from discharge values. The doses represents the adult population.

Doses from emissions to atmosphere were determined using the PC CREAM model[5].

Variations in liquid discharges and therefore in the doses to these individuals are caused by variation in the research activities and production of radiopharmaceuticals and other radionuclides at IFE Kjeller.

2.1.8 Summary of BAT/BEP for the Kjeller site

Based on the evaluation of BAT/BEP concerning discharges, environmental impact and radiation dose to the public it is generally concluded that BAT/BEP is applied at IFE Kjeller during the time period covered by this report.

2.2 Institute for Energy Technology, Halden

Halden Boiling Water Reactor (HBWR), a heavy water cooled and moderated research reactor (25 MW). HBWR has three main systems, the primary system (heavy water) and two light water heat removal systems, where the secondary system is a closed loop system. The reactor was permanently shut down in 2018. As indicated above, some of the fuel from HBWR has been removed; some fuel and heavy water remain in place pending defuelling operations.

[4] IAEA Safety Reports Series No. 19 *Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment* (2001)

[5] Simmonds J.R., Lawson G. and Mayall A., *Methodology for assessing radiological consequences of routine releases of radionuclides to the environment,* European Commission, EUR 15760 EN, ISSN 1018-5593, (1995)

HBWR is located in Halden, in the south-eastern part of Norway. The containment with the reactor and primary system is located in a mountain hall.

2.2.1 Activities from which liquid effluents arise

2.2.2 Systems in place to reduce, prevent or eliminate liquid discharges

There have been no new systems in place since the previous report, which described the following systems, which remain in place:

- → Drainage and delay system
- → Ion exchange and evaporation
- → He-3 decontamination system

Drainage and delay
This system is designed for collection and disposal of waste water. Water is directed to and flows through a 10 m^3 delay tank, where sedimentation of some of the activity will occur. Activity monitoring is performed continuously on the water leaving the tank to the sewage system. In case of abnormally high water activity, a main outlet valve will close automatically, and the water is directed to storage and delay tanks with a total capacity of 90 m^3. The water can then be cycled through a clean-up system with particle filters and ion exchange resin and discharged after control of activity.

The largest by volume of liquid discharge from HBWR is drainage of groundwater from the mountain hall. The water is slightly contaminated, primarily with tritium, and is transferred directly to the 10 m^3 delay tank. An increase in activity will be detected by a monitoring system before the water reaches the delay tank and the water is then immediately directed to the storage and delay tanks, where clean-up can be performed.

Discharge water from non-radioactive systems at the chemistry laboratories is collected in separate tanks and discharged after measurements of activity. The tanks are equipped with an ion exchange clean-up system in case of radioactivity in the discharge water exceeds specific IFE reference levels that are related to the target values for doses to the critical group, explained below.

Discharge water from the plant laundry is transferred to a collection tank with a sludge interceptor and particle filters. The water from the tank is released after measurement of radioactivity. If the radioactivity concentration is above nuclide-specific reference levels the water is treated by filtration and ion-exchange before discharge.

Ion exchange and evaporation
Liquids from the experimental circuits are cycled through filters and ion exchange columns multiple times such that the activity is very low before it is discharged. Liquids from the laboratories are evaporated to a collection tank and discharged after measurement of activity.

He-3 decontamination system
A source of tritium to the liquid discharge is diffusion of tritium from He-3 coils. The He-3 system contains an advanced purification system in which tritium gas is absorbed on a titanium filter. In addition, to avoid diffusion of tritium through coils, an oxidised steel alloy is used in these types of experiments.

Efficiency of abatement systems
The efficiency of the sedimentation process in the delay tank is nuclide dependent. The sedimentation is measured to 10 – 20 % for transition metals (Mn, Co, Zr, Nb), about 2% for alkali metals (Cs) and 4% for lanthanides (Ce). For the laundry water system, a separate tank for sludge sedimentation has been installed. The efficiency of the abatement through sedimentation is measured to be 15 - 40 % for transition metals (Mn, Co, Zr, Nb, Cr) and about 8 % for alkali metals (Cs).

The efficiency of abatement of discharges from experimental circuits (multiple filtration and ion-exchange) and from the laboratories (evaporation) is better than 95 % for all nuclides except tritium. The efficiency of the abatement of activity collected in the storage, delay tanks and chemistry laboratory tank (filtration and ion-exchange) is better than 95 %. The efficiency of the purification of laundry water is better than 90 %.

With respect to emissions to atmosphere, filtration systems with HEPA filters and charcoal filters have been installed in the ventilation systems from fuel handling compartments, containment and other buildings where work with irradiated fuel can result in emissions of radioactive aerosols. Emissions of radioactivity though the filters are continuously monitored. Filters are replaced if measurements show a reduced efficiency. Their efficiency is estimated to be around 99%.

2.2.3 Annual liquid discharges

Annual liquid discharges of various nuclides to the river Tista in 2016-2021 are given in Table 8.

Table 8 Annual liquid discharges of various nuclides to the river Tista in 2016-2021

	Annual liquid discharge (MBq)					
Radionuclides	2016	2017	2018	2019	2020	2021
H-3	8.6E+05	4.2E+05	2.9E+05	1.6E+5	1.5E+5	1.2E+05
Cr-51	13	0.034	1.1E-01			
Mn-54	0.029	0.0076	3.9E-04	2.3E-3		0
Fe-59	0.09					
Co-58	0.18	0.04	2.7E-1	2.6E-2		0
Co-60	9.5	8.2	4.5E0	1.5E0	4.5E-1	0.38
Zn-65		0.00072				
Sr-90	1.1	1.5	1.48E0	4.6E-1	2.6E-1	0.14
Zr-95	1.9	1.2	1.1E-1			
Nb-95	4.1	2.3	2.2E-1	3.7E-3		0
Ru-103	0.75	0.33	2.5E-2			
Ru-106		0.058				
Ag-110m	1.4	0.41	5.0E-2			
Cd-109	0.39	0.11	1.8E-1	6.7E-2		0
Sb-124		0.0065	2.4E-4			
I-131	28	0.31	5.6E-2			
Cs-134	1.5	1.4	4.1E-1	1.4E-1	3.1E-2	0.014
Cs-137	40	31	1.8E+1	7.7E0	4.9E0	3.00
Ba-140	0.023					

	Annual liquid discharge (MBq)					
Radionuclides	2016	2017	2018	2019	2020	2021
La-140	0.077		2.9E-1			
Ce-141	0.58	0.29	7.1E-2	2.6E-3		0
Ce-144	0.79	1.8	6.8E-2			

The low activity levels in the liquid discharge vary and are related to the variation in the type and number of research activities.

The reactor ceased operating in June 2018, which has resulted in a reduction in the discharges.

The elevated discharge of I-131 in 2016 is due to an incident with breach in fuel rods in the handling compartment in the reactor hall.

2.2.4 Emissions to air

Table 9 Annual emissions of ^{3}H from IFE-Halden 2016-2021.

Emission of tritium to the atmosphere (TBq)					
2016	2017	2018	2019	2020	2021
26	23	13	1.5	2.0	0.76

2.2.5 Environmental impact

The environmental monitoring programme relevant to the Halden site includes:

- → Bottom sediment from two locations in the river Tista, twice per year;
- → Bottom sediment from previous discharge area in the river Tista, once per year;
- → Sediment samples from sand beaches along the fjord, once per year;
- → Fish from two locations in Iddefjord, once per year;
- → Grass from neighbouring farms, twice per year;
- → Precipitant (rain, snow) from two locations, once per fortnight;

Water from three locations in the river Tista, twice per year

2.2.6 Systems for quality assurance of environmental monitoring program

In 2011, IFE was certified to the ISO 9001 and ISO 14001 standards.

IFE Halden has a comprehensive quality control and assurance system where all work tasks, including measurement of activity, are described in detail in working instructions and procedures.

Concentrations of radionuclides in representative samples of water, sediment and fish

Table 10 shows the average concentration of Cs-137 in shore sand and fish samples collected in the Iddefjord and sediment and water samples from the river Tista, above and below the discharge point from the reactor site. Since 2016, river water samples have also been taken from a location upstream from the discharge point from the reactor, but downstream from the release from the adjacent paper mill.

Table 10 Activity concentrations of Cs-137 in water, sediment, sand, and fish in the vicinity of the Halden site (Bq/kg)

	Activity concentrations of Cs-137 in environmental samples (Bq/kg)						
	Shore sand (4 beaches)	Fish samples	River sediment upstream	River sediment downstream	River water upstream both paper mill and reactor	River water downstream paper mill and upstream reactor	River water downstream both paper mill and reactor
2016	2.0	0.5	36	15	0.0008	0.0060	0.0043
2017	1.6	0.5	21	11	0.0011	0.0057	0.0058
2018	1.8	0.6	26	8.6	0.0015	0.0057	0.0063
2019	1.9	0.5	24	12.8	0.0009	0.0064	0.0032
2020	1.4	0.3	20	9	0.0005	0.0086	0.0068
2021	1.8	0.49	37	12.1	0.0005	0.0012	0.0012

The measured activities of anthropogenic nuclides in the environmental samples are very low, although they include a significant contribution from the Chernobyl fallout. Therefore, the BAT/BET indicators are considered to be met, although there is no significant downward trend observed.

2.2.7 Radiation doses to the public

The average annual effective dose to the representative person from liquid discharges and emissions to atmosphere from HBWR is shown in Table 11.

Table 11 Annual effective doses to the representative person from Halden

	Annual effective dose to the representative person (µSv)					
	2016	2017	2018	2019	2020	2021
Liquid discharges	0.002	0.001	0.0005	0.00018	0.000094	0.000064
Total (incl. atmospheric emissions)	3.0	2.0	1.1	0.11	0.14	0.05

The total exposure from both liquid discharges and releases to the atmosphere, assuming that the representative persons are the same for each form of release, are dominated by the contribution from emissions to the atmosphere.

The representative person is hypothetical and defined by their food consumption and living habits, summarized as follows:

- → Annual consumption of 30 kg of fish from the part of the Iddefjord close to the discharge of the river Tista;
- → 200 hours/year occupancy on the beaches in the part of the Iddefjord close to the discharge from the river Tista;
- → 50 hours of bathing in the fjord and 1000 hours/ year of boating.

The estimation of doses to the representative person is based on theoretical radionuclide concentration in the environment, calculated from discharge values.

All modelling of transfer of radionuclides in the environment and doses to critical groups are based on the PC CREAM methodology[2].

The trends in discharges and doses are associated with variations in research and clean-up activities.

2.2.8 Summary of BAT/BEP for Halden site

Based on the evaluation of BAT/BEP concerning discharges, environmental impact and radiation dose to the public it is generally concluded that BAT/BEP is applied at IFE Halden during the time period covered by this report.

OSPAR Secretariat
The Aspect
12 Finsbury Square
London
EC2A 1AS
United Kingdom

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

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

Publication Number: 937/2023