OSPAR COMMISSION

Protecting and conserving the North-East Atlantic and its resources

Seventh Norwegian Implementation Report of PARCOM Recommendation 91/4 on radioactive discharges

Radioactive Substances Series

2019

Norway’s report on the implementation of PARCOM recommendation 91/4 on radioactive discharges for 2018

OSPAR Convention

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

Convention OSPAR

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

This report has been produced as part of the sixth round of implementation reporting on PARCOM recommendation 91/4, where Norway was scheduled to report to the meeting of the OSPAR Radioactive Substance Committee in 2014. The report is outlined according to the guidelines for the submission of information about, and the assessment of, the application of BAT in nuclear facilities (2004-03).

The first section gives general information regarding national legislation, dose limits, discharge limits etc. Section 2 and 3 give site specific information about each of the two nuclear installations (research reactors).

Contents

1. General Information

1.1 Implementation of BAT/BEP in terms of the OSPAR Convention in Norwegian legislation/regulation

The Pollution Control Act 13 March 1981 has applied to radioactive pollution (including discharges and releases) and radioactive waste since 1 January 2011. Under this Act, pollution is forbidden unless specifically permitted by law, regulations or individual permits. The objective of the Act is to secure a satisfactory environmental quality based on a balance of interests, which includes costs associated with any measures and other economic considerations. Pursuant to the Act, three regulations concerning radioactive pollution and radioactive waste have been issued:

- Regulation on the application of the Pollution Control Act on Radioactive Pollution and Radioactive Waste of 1 November 2010. This regulation defines radioactive pollution and radioactive waste.
- Regulation on the Recycling of Waste of 1 June 2004. This regulation establishes requirements for waste in general, chapter 16 deals specifically with radioactive waste.
- Regulation on Pollution control of 1 June 2004. This regulation defines procedures for applications for permits and establishes administrative provisions for radioactive pollution and waste.

Nuclear installations are also regulated in accordance with the Nuclear Energy Act 12 May 1972 on Nuclear Energy Activities, the Radiation Protection Act on Radiation Protection and Use of Radiation 12 May 2000 and the Regulation on Radiation Protection and Use of Radiation 29 October 2010.

When issuing authorisations for nuclear installations, Norwegian practice is to focus on BAT, the ALARA principle and the precautionary principle. Use of BAT regarding discharge of radioactive substances is implemented under the Pollution Control Act 13 March 1981 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 results in the light of an overall evaluation of current and future use of the environment and economic considerations.

1.2 National authority responsible for supervision of discharges

Licensing and supervision of the operation of nuclear sites is carried out by the Norwegian Radiation Protection Authority (NRPA)[1]. NRPA is the Government's competent authority on matters concerning radiation protection and nuclear safety and security. It is organised as a directorate under the Ministry of Health and Care Services, from which it primarily receives its funding. NRPA is also a directorate under the Ministry of Climate and Environment with respect to releases to the environment and waste from nuclear and non-nuclear industries, and under the Ministry of Foreign Affairs with respect to implementing safety measures under the Action Plan for Nuclear Safety in North West Russia and Ukraine, and under the Ministry of Defence concerning the traffic

[1] From 1 January 2019, the NRPA changed its name. The name is now the Direktoratet for strålevern of atomsikkerhet (DSA), or the Norwegian Radiation and Nuclear Safety Authority in English.

of nuclear submarines along the Norwegian coast. NRPA also provides assistance and advice to other ministries on matters related to radiation protection, radioactive waste management, nuclear safety and security.

1.3 Dose constraints/limits for nuclear facilities

The effective dose limit for members of the public and non-occupationally exposed workers from ionizing radiation, specified in the Regulations on Radiation Protection and Use of Radiation, is 1 mSv/year. These regulations also specify a dose constraint of 0.25 mSv/year.

The operational limits and conditions for discharges from nuclear facilities at Kjeller and Halden (operated by the Institute for Energy and Technology (IFE)) are specified in permits according to the Pollution Control Act granted by the NRPA. The existing discharge permits specify that the maximum permitted doses to the population group most likely to be exposed (referred to below as the critical group) must be below 1 µSv/year for liquid discharges and below 100 µSv/year for discharges to the air, within which the dose contribution from iodine isotopes shall be below 10 µSv/year.

1.4 Discharge limits

Since 2014, the NRPA has defined radionuclide-specific discharge limits for the nuclear facilities. Restrictions on discharges have been through activity levels in the effluent water. In addition, the facilities must ensure that the dose constraints and limits are not exceeded for the sum of all radionuclides discharged.

The radionuclide specific discharge limits are specific for each of the nuclear facilities and are based on the ALARA principle, taking account of historical discharge data and planned changes in research activity, while ensuring compliance with the dose limits.

1.5 Monitoring programmes of environmental concentrations of radionuclides

The operators of the research reactors are required to carry out environmental monitoring, according to the conditions of their authorisations to discharge (see section 2.3.2, 2.3.4 and 3.3.2 for details). The results are annually reported to the NRPA.

In the discharge authorisations issued by the NRPA, it is also required that the operators carry out measurements of their discharges to water and air. These measurements are conducted according to a program approved by the NRPA and the results of the monitoring programs are annually reported to the NRPA.

In addition to the environmental monitoring programs carried out by the operators, the NRPA coordinates national monitoring programs for radioactivity present in the marine and terrestrial environments. The marine monitoring program was established in 1999. The principal objective of the 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. For example, the report for radioactivity in the marine environment for 2012-2013 and 2014 can be found at: https://www.nrpa.no/publication/nrpa-report-2017-13-radioactivity-in-the-marine-environment-2012-2013-and-2014.pdf

1.5 Environmental norms and standard (other than dose standards for humans)

Action limits for the activity concentrations of Cs-137 and Cs-134 in foods exist for activity present in the environment as a consequence of the Chernobyl accident. Otherwise, the degree of protection of the environment is primarily based on the protection of human health through the application of dose constraints/limits. However, the NRPA has been closely engaged in the activities of the International Union of Radioecology and the International Commission on Radiological Protection to develop a framework for the protection of the environment from ionizing radiation, and this work is contributing to the development of environmental norms and standards and the development and application of relevant assessment methodologies.

1.6 Nature of inspection and surveillance programmes

The sites of the nuclear research reactors are inspected by the NRPA on a regular basis with regard to nuclear safety, radiation protection and environmental protection. A part of the inspection is the assessment of the annual reports from the Institute for Energy Technology on environmental monitoring and routine measurements of discharges.

2. Site–Specific Information - Institute for Energy Technology, Kjeller

2.1 Site characteristics

2.1.1 Name of site

Institute for Energy Technology, Kjeller, Norway (IFE Kjeller)

2.1.2 Type of facility

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

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

c) Storage areas for fresh fuel and spent fuel.

d) Radioactive Waste Treatment Plant for low lever (LL)- and intermediate level (IL) waste.

e) Medical Radioactive Isotope Facility.

2.1.3 Year of commissioning/licensing/decommissioning

The JEEP II reactor was commissioned in 1966.

Current licence period for facility a) – d) in 2.2 is 1 January 2009 – 31 December 2018. An application for a renewed licence for facility a) – d) has been submitted to the NRPA. A licence for operation of facility e) is not required according to the Nuclear Energy Act 12 May 1972.

A production line for the radiopharmaceutical product Xofigo has been in operation since 2013.

2.1.4 Location

Institute for Energy Technology Kjeller, about 20 km north-east of Oslo.

2.1.5 Receiving waters and catchment area, including, where relevant, information on water flow of receiving rivers

All liquid effluents from the facilities are pumped to the radioactive Waste Treatment Plant. After treatment, these effluents are discharged to the river Nitelva, which is about 100 km from the sea. The river, having an annual mean flow of 5 m^3/s leads into Lake Øyern where the water is mixed with the water of river Glomma having an annual mean flow of 400 m^3/s. Glomma river empties into the Oslo Fjord, which has an open connection with Skagerrak (OSPAR region II).

2.1.6 Production

The thermal effect of the JEEP II research reactor is 2 MW.

The Radioactive Waste Treatment Plant receives and manages radioactive LL- and IL waste from Norwegian industry, universities, hospitals and other research institutes as well as from IFE's 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.

2.1.7 Other relevant information

Not relevant.

2.2 Discharges

2.2.1 Systems in place to reduce, prevent or eliminate discharges of radioactive substances to the marine environment

The discharge limit is authorised by the NRPA. 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 members in a critical group in the population along the river Nitelva.

The 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 (appendix 1) 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 the gamma and tritium results do not indicate anomalies, determination of long lived alpha and beta emitting radionuclides, such as ^{90}Sr, uranium-, plutonium-, americium- and curium isotopes, is performed 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. If gamma and tritium results indicate higher levels than normal, the waste water is retained until all analyses are completed.

No new systems have been taken into operation during the reporting period. Through the authorisation for release of radioactive substances, the operator is obliged to limit the discharge to levels as low as reasonable achievable (ALARA) and use of best available technology (BAT) in order to achieve this. Equipment, methods and routines are continuously evaluated for potential discharge reducing measures, including measures to enhance worker awareness of the issue. In any effort to reduce discharges, the resulting discharge reduction are considered in view of, among other things, the doses incurred by occupationally exposed individuals and the economic investment necessary to achieve the reduction. Since the current discharge levels and resulting doses to the public are very low, evaluation of possible major new installations often reveal that the doses or investment involved in implementing additional measures do not justify the marginal reduction in discharge that could be achieved. The best dividends 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 revised control routine to ensure that there is no leakage of waste water 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. The waste water flow through the NALFA pipeline is controlled by measuring the flow at the start and end of the pipeline. In addition, a pressure test on the NALFA pipeline is performed by an external company on a yearly basis.

For emissions to the air the NRPA has authorised nuclide specific discharge limits. In addition, the discharge is limited to an annual dose of 100 µSv to members in a critical group in the population 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 members in the same critical group.

2.2.2 Efficiency of abatement systems

No changes to the abatement systems have been introduced during the last six years. The discharges have been so small that major investments cannot be justified given the minor reductions in annual dose to the critical group that would be achieved.

During the last six years some changes in the environmental monitoring program has been introduced to improve monitoring efficiency. For instance, yearly sampling and analyses of water and particles from manholes along the storm water drainage pipe at the facility has been included in the programme.

An application for a revised environmental monitoring program, more adjusted to ongoing activities at the site (e.g. increased production and research on radiopharmaceuticals), has been submitted to the NRPA.

Liquid discharges

The following abatement systems for liquid radioactive waste have been in operation for several years.

- Delay tanks
- Ions exchange filtration system
- Vacuum evaporation system

All liquid waste produced in IFEs facilities at Kjeller are treated at the Radioactive Waste Treatment Plant by one of the abatement systems above. The efficiencies are given in appendix 1. The efficiencies given for the ion exchange system and the evaporation system do not include abatement of ^{3}H.

Emission to the atmosphere

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 ventilation system from production cells and facilities where volatile radioactive materials are used, active charcoal filters are installed and in use. The efficiencies are given in appendix 1.

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

2.2.3 Annual liquid discharges

Annual liquid discharges of various nuclides to the Nitelva river in 2012-2017 are given in table 2.1.

Table 2.1 Annual liquid discharges from IFE-Kjeller 2012-2017

Radio-nuclides	2012 * (MBq)	2013 (MBq)	2014 (MBq)	2015 (MBq)	2016 (MBq)	2017 (MBq)
^{3}H		933 000	6 800	915 000	1 052	32
^{90}Sr		2.83	0.012	0.65	0.0235	0.0097
^{134}Cs		0.066				
^{137}Cs		1.83	0.035	2.29	0.025	0.025
^{125}I						
^{131}I						
^{60}Co		2.26	0.076	1.62	0.077	0.0122
^{54}Mn						
^{65}Zn						
^{239}Pu		0.126	0.0051	0.0453	0.319	0.0108
^{240}Pu		0.0066	0.00027	0.0024	0.017	0.00057
^{238}Pu		0.0007		0.00088	0.00274	0.00043
^{241}Am		0.0023	0.00015	0.0168	0.0046	0.00095
^{51}Cr						
^{59}Fe						
^{58}Co						
^{103}Ru						
^{106}Ru						
^{124}Sb						
^{125}Sb						
^{144}Ce						
^{110m}Ag				0.0365		
^{95}Zr						
^{95}Nb						
^{234}U		0.056	0.00098	0.14	0.0056	0.00101
^{235}U		0.0023		0.0095	0.00015	0.00004
^{238}U		0.058	0.00074	0.14	0.0056	0.00084
^{243}Cm						

Radio-nuclides	2012 * (MBq)	2013 (MBq)	2014 (MBq)	2015 (MBq)	2016 (MBq)	2017 (MBq)
^{244}Cm		0.00019		0.00225	0.00062	0.000095
^{22}Na						
^{133}Ba		0.126		0.193		
^{223}Ra				0.0609	1.8	0.148
^{227}Th					0.056	0.0024

* No discharges to water in 2012.

Total annual liquid discharges in % of the authorised limit are given in table 2.2:

Table 2.2 Total annual liquid discharge in % of the authorised limit from IFE-Kjeller 2012-2017.

	2012	2013	2014	2015	2016	2017
% of limit	0	0.74	0.012	0.84	0.018	0.008

There is no downward trend in discharges of liquid radioactive waste. Variations in liquid discharges are caused by variation in the research activities and production of radiopharmaceuticals and other radionuclides at IFE Kjeller.

2.2.4 Emissions to air

The main emissions to air from the facilities at Kjeller are ^{3}H and ^{41}Ar from JEEP II operation. In addition, small discharges of eg. ^{82}Br, ^{85}Kr and ^{131}I from other activities occur. Table 2.3 shows the activity in the annual emissions.

Table 2.3 Annual emission of ^{3}H, ^{125}I and ^{137}Cs from IFE-Kjeller 2012-2017

Radio-nuclides	2012 * (GBq)	2013 (GBq)	2014 (GBq)	2015 (GBq)	2016 (GBq)	2017 (GBq)
$^{3}H^{1}$	4 400	7 054	7544	7771	5 138	6 066
$^{41}Ar^{1}$	23 100	14 188	15173	15631	13 615	16 067
^{82}Br	0,0528	0,00010	0,00021	0,22	0,00096	0,052
$^{85}Kr^{1}$					90,7	16,9
^{131}I	3,93	0,0044	0,0098	0,0055	0,0067	0,0467

2.2.5 Systems for quality assurance

IFE's internal Health and Safety Department 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. To ensure that the discharges are carried out correctly, several control procedures related to the technical condition of the pipeline and procedures to verify that discharges actually reach the discharge point in Nitelva river. Prior to discharges IFE's internal Health and Safety Department measures the nuclide content and activity levels in the waste water to ensure that the nuclide specific discharge limits are not exceeded. Emissions to air are measured and analysed weekly and are documented in a database at IFE's internal Health and Safety Department. Discharges to water and to the atmosphere are reported to IFE's board of directors every three months and yearly in a report to NRPA.

In 2018, IFE was recertified to the ISO 9001 and ISO 14001 standards. Whereas the ISO9001 involves standard for quality management systems, the ISO 14001 is a standard for environmental management.

2.2.6 Site specific target discharge values

Discharges of liquid effluents are related to the discharge limits given by the NRPA and described in section 2.2.1 above.

Through the authorisation for release of radioactive substances, the operators are obliged to limit the discharge to levels as low as reasonable achievable (ALARA) and use the best available technology (BAT) in order to achieve this. Equipment, methods and routines are continuously evaluated for potential discharge reducing measures.

2.2.7 Any relevant information not covered by the requirements specified above

Not relevant.

2.2.8 Explanations for lack of data or failure to meet BAT/BEP indicators, as well as, when appropriate, a description of on-going or planned activities.

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

Emission of ^{3}H is due to the operation of the JEEP II reactor and no downward trend in this emission can be expected.

2.2.9 Summary evaluation

Table 2.4 summarizes the evaluation of BAT/BEP for IFE Kjeller concerning discharge.

Table 2.4 Summary evaluation of discharges from IFE Kjeller.

Criteria	Evaluation
BAT/BEP indicator	
• Relevant systems in place	Yes
• Abatement factor	Normal for existing abatement systems
• Downward trend discharges	No downward trend, variation in liquid discharge is caused by variations in research activity and waste treatment
• Downward trend discharge normalized	Not applicable
• Downward trend emission	No downward trend, variation in emission is caused by variations in research activity.
• Relevant and reliable QA systems	Yes
• Relevant site specific target values	Target values not implemented
Data completeness	Complete
Causes for deviations from indicators	See text section 2.2.8
Uncertainties	No impact on the conclusions
Other information	None

2.3 Environmental impact

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

Table 2.5 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 2.5 Average concentrations in mBq/l of radionuclides in representative samples of water from three locations in the Nitelva river.

Year	Location VA 1	Location VA 4	Location VA 5

	^{90}Sr	$^{239,240}Pu$	^{90}Sr	$^{239,240}Pu$	^{90}Sr	$^{239,240}Pu$
2012	4,7 (3)	0,11 (1)	4,1 (3)	- (0)	4,6 (3)	- (0)
2013	4,6 (3)	- (0)	5,7 (3)	- (0)	5,5 (3)	- (0)
2014	4,3 (3)	- (0)	4,6 (3)	- (0)	4,2 (3)	- (0)
2015	3,3 (3)	- (0)	3,6 (3)	- (0)	3,8 (3)	- (0)
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)

The numbers in parenthesis are number of samples exceeding the detection limit that is the basis for calculation the average concentration.

Table 2.6 shows the concentration in Bq/kg of radionuclides in samples of sediments 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 2.6 Concentrations in Bq/kg of radionuclides in representative samples of annealed sediments from three locations in the Nitelva river. The results are form the top 10 cm of sediments

SD 1	^{137}Cs	$^{239,240}Pu$	U_{nat}	^{90}Sr
2012	7,9 ± 0,7	0,10 ± 0,06	20 ± 4	1,12 ± 0,24
2013	19,1 ± 1,7	0,22 ± 0,07	63 ± 15	1,4 ± 0,4
2014	18,2 ± 1,6	0,15 ± 0,09	34 ± 7	2,7 ± 0,5
2015	16,3 ± 1,3	0,12 ± 0,07	40 ± 8	0,9 ± 0,4
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
SD 4	^{137}Cs	$^{239,240}Pu$	U_{nat}	^{90}Sr
2012	27,8 ± 2,1	3,2 ± 0,8	40 ± 7	1,4 ± 0,4
2013	41,7 ± 2,5	7,0 ± 1,0	36 ± 7	1,2 ± 0,4
2014	48 ± 4	20 ± 4	47 ± 11	2,3 ± 0,4
2015	11,8 ± 0,9	16,2 ± 2,9	30 ± 8	1,00 ± 0,26
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
SD 5	^{137}Cs	$^{239,240}Pu$	U_{nat}	^{90}Sr
2012	6,0 ± 0,7	1,2 ± 0,4	38 ± 7	0,56 ± 0,30
2013	20,9 ± 1,5	4,9 ± 1,2	50 ± 10	0,7 ± 0,5
2014	27,4 ± 1,8	2,7 ± 0,4	36 ± 11	1,06 ± 0,27
2015	19,7 ± 1,3	2,03 ± 0,29	36 ± 8	1,1 ± 0,4
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

Table 2.7 shows the average concentration of radionuclides in fish of all types during the last six years. The results are in Bq/kg wet weight.

Table 2.7 Concentrations in Bq/kg of radionuclides in fish of all types. The results are for wet weight samples

Year*	^{137}Cs **	$^{239,240}Pu$ **	^{90}Sr
2012 (4)	2,6 ± 4,7	0,016 ± 0,003 (1)	1,1 ± 1,8
2013 (3)	1,6 ± 3,8	- (0)	0,11 ± 0,05
2014 (6)	1,5 ± 1,9	- (0)	0,079 ± 0,079
2015 (2)	0,58 ± 0,11	0,0007 ± 0,0005 (1)	0,15 ± 0,07
2016 (3****)	1,52 ± 0,15	0,0029 ± 0,0018 (2)	0,84 ± 0,07
2017 (2)	2,17 ± 0,22	- (0)	0,15 ± 0,07

* The total number of samples is given in parenthesis

** The numbers in parenthesis are the number of samples where the nuclide has been measured

2.3.2 Environmental monitoring programme, frequency of sampling, organisms

The environmental program for Nitelva river is operated by IFE's internal Health and Safety Department and includes samples from the river water, sediments, fish and water plants. The following programs have been approved by the NRPA:

- Water samples: Three times a year at 6 locations in the river.
- Sediments: Once a year at 6 locations in the river.
- Water plants: Are collected twice a year at one location in the river
- Fish: Fishing of species used for consumption during the summer period.

The radioactivity content are analysed in the laboratories of IFE's internal Health and Safety Department and reported yearly to the NRPA.

2.3.3 Systems for quality assurance of environmental monitoring program

In 2018, IFE was re-certified to the ISO 9001 and ISO 14001 standards. Whereas the ISO9001 involves standard for quality management systems, the ISO 14001 is a standard for environmental management.

IFE's internal Health and Safety department has a comprehensive quality control and assurance system where all work tasks, including measurements of activity are described in detail in working instructions and procedures. Criteria for non-conformity are also defined in these procedures. The department is a member of the International Atomic Energy Agency (IAEA)'s ALMERA network of radioanalytical laboratories for analysis of environmental samples.

2.3.4 Any relevant information not covered by the requirements specified above

In addition to the environmental program in the Nitelva river, IFE's internal Health and Safety Department has a comprehensive program for monitoring of radioactivity in the proximity of the IFE site and in nearby food production from emission and fallout from operation of nuclear facilities. This includes measurements of the following samples:

- Outdoor air

- Precipitation
- Gras
- Milk
- Agricultural products

2.3.5 Explanations for lack of data or failure to meet BAT/BEP indicators, as well as, when appropriate, a description of on-going or planned activities

The main bulk of data from analyses of the water samples, sediments and fish show low values and can therefore be interpreted as to meet the 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.

2.3.6 Summary evaluation

Table 2.8 summarizes the evaluation of BAT/BEP for IFE Kjeller concerning environmental impact.

Table 2.8 Summary evaluation of environmental impact.

Criteria	**Evaluation**
BAT/BEP indicator	
• Downward trend in concentrations	Low concentrations, but no downward trend
• Relevant monitoring program	Yes
• Relevant and reliable QA system	Yes
Data completeness	Complete
Causes for deviations from indicators	See text in section 2.3.5
Uncertainties	No impact on the conclusions
Other information	Monitoring of radioactivity in the proximity of IFE and in nearby food production from emission and fallout are in place

2.4 Radiation doses to the public

2.4.1 Average annual effective dose to individuals within the critical group

Average annual effective dose to individuals within the critical group from liquid discharges from IFE Kjeller are given in table 2.9. The corresponding doses to the critical group from atmospheric discharges is given in table 2.10.

Table 2.9 Average annual effective dose to individuals within the critical group from liquid discharges

	2012	2013	2014	2015	2016	2017
µSv to critical group	0	0.0074	0.00012	0.0084	0.00018	0.00008

Table 2.10 Average annual effective dose to individuals within the critical group from atmospheric discharges

	2012	2013	2014	2015	2016	2017
µSv to critical group	2.34	1.91	2.05	2.12	1.67	1.99

2.4.2 Total exposures

The total annual effective doses to the public for discharges to the Nitelva river and from emissions to the air cannot be measured and are based on model calculations based on exposure pathways and public behaviour. The total doses to the public from liquid discharges are given in section 2.4.1 above and include historical discharges. The total annual effective doses to individuals in the critical group from emission to the atmosphere are given above.

The critical groups for liquid discharges and emissions to the air are not the same and the doses should therefore not be added.

2.4.3 The definition of the critical group(s)

The critical group is hypothetical and defined by their food consumption and living habits. The estimation of doses to the group is based on theoretical radionuclide concentration in the mentioned local river environment situated 100 km from the sea and calculated from discharge values. The doses represent the adult population. It has been established that children, taking their habits into account, do not receive doses that deviate significantly from adults. The total population around lake Øyern was 83 811 people in 2010. The age distribution is given in table 2.11.

Table 2.11 Age distribution in population all the municipalities around the lake Øyern

Group	Age (years)	% of population
Infant	0 - 2	3.3
Child	2 -17	19.7
Adult	>17	77.0

2.4.4 Information on exposure pathway(s)

The calculation of effective dose to the critical group is based on:

- 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.

2.4.5 Basis for methodology to estimate doses

Modelling of transfer of radionuclides in the environment and doses to critical groups from discharges to water have for the reporting period been based on recommendations from the IAEA described in:

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

Modelling of transfer of radionuclides in the environment and doses to critical groups from discharges to the atmosphere have for the reporting period been based on the use of the code PC-CREAM (EUR 17791 EN (NRPB-SR296), UK 1997). The code uses the model described in:

> 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)

2.4.6 Site-specific factors

No site specific factors are used except for the K_d factor for ^{60}Co and ^{137}Cs that is determined by IFE's Health and safety Department for the actual river sediments. The estimates are otherwise based on default values from the references in section 2.4.5.

2.4.7 Site specific target annual effective dose

The discharge limits defined by the NRPA are based on a limiting annual effective dose of 1 µSv to individuals in the critical group. Target values are not implemented.

2.4.8 Systems for quality assurance of processes involved in dose estimates

There are no measurements involved in the dose assessments except for the use of local values for K_d. The calculations have been tested against example calculations from the reference in section 2.4.5.

2.4.9 Any relevant information not covered by the requirements specified above

Not relevant.

2.4.10 Explanations for lack of data or failure to meet BAT/BEP indicators

There are no downward trends for doses from liquid discharges. 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.

2.4.11 Summary evaluation

Table 2.12 summarizes the evaluation of BAT/BEP for IFE Kjeller concerning radiation dose to the public.

Table 2.12 Summary evaluation of radiation dose to the public

Criteria	Evaluation

BAT/BEP indicator	
• Downward trend in radiation dose, critical groups	Low doses, but no downward trend. Caused by variations in the research activity and waste treatment
• Total exposure within the constraint	Yes
• Relevant critical groups	Yes
• Reliable dose estimates	Yes
• Relevance of target dose	Target dose not implemented
• Relevant and reliable QA system	Yes
Data completeness	Yes
Causes for deviations from indicators	See text section 2.4.10
Uncertainties	No impact on the conclusions
Other information	None

2.5 Summary BAT/BEP

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.

3. Site–Specific Information - Institute for Energy Technology, Halden

3.1 Site characteristics

3.1.1 Name of site

Institute for Energy Technology, Halden, Norway (IFE Halden)

Halden Boiling Water Reactor (HBWR)

3.1.2 Type of facility

Heavy water cooled and moderated research reactor. 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.

3.1.3 Year of commissioning/licensing/decommissioning

Commissioned: 1959

Current licence: Expiry date 31/12-2020[2]

3.1.4 Location

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

3.1.5 Receiving waters and catchment area, including, where relevant, information on water flow of receiving rivers

Liquid discharge is released to the river Tista which empties into Iddefjord, leading to Skagerrak (OSPAR region II). The average flow of the river Tista is 21 m^3/s. The volume of Iddefjord is $4 \cdot 10^8$ m^3, the average outflow to Skagerrak is 180 m^3/s and average inflow from Skagerak is 150 m^3/s.

3.1.6 Production

The maximum heat removal capacity is 25 MW. The heat is transferred from the tertiary system to an adjacent paper mill as steam. The primary system operates with a water temperature of 235 °C, corresponding to an operating pressure of 33.4 bars.

[2] On 27 June 2018, IFE announced that the Halden reactor would permanently close and that decommissioning would start.

3.1.7 Other relevant information

Not relevant.

3.2 Discharges

3.2.1 Systems in place to reduce, prevent or eliminate discharges of radioactive substances to the marine environment

Drainage and delay system

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.

No new systems, processes or changes in management are planned to be introduced for liquid waste treatment in the near future.

3.2.2 Efficiency of abatement systems

Liquid discharge

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 clean-up 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 clean-up 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 %.

Emission to the 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. The efficiencies are given in appendix 2. Emissions of radioactivity though the filters are continuously monitored. Filters are replaced if measurements show a reduced efficiency.

3.2.3 Annual liquid discharges

Annual liquid discharges of various nuclides to the river Tista in 2012-2017 are given in table 3.1.

Table 3.1 Annual liquid discharges from IFE-Halden 2012 - 2017

SITE	Radio-nuclides	2012 MBq	2013 MBq	2014 MBq	2015 MBq	2016 MBq	2017 MBq
Institute for Energy Technology Halden Boiling Water Reactor	H-3	8.5E+05	8.4E+05	1.1E+06	6.6E+05	8.6E+05	4.2E+05
	Cr-51	12	29	59	22	13	0.034
	Mn-54	0.20	0.071	0.023	0.067	0.029	0.0076
	Fe-59	0.29	0.23	0.10	0.10	0.09	
	Co-58	1.20	1.11	0.90	1.14	0.18	0.04
	Co-60	33	17	18	14	9.5	8.2
	Zn-65	0.040	0.0058	0.0063			0.00072
	Sr-90	5.7	6.2	4.4	5.9	1.1	1.5
	Zr-95	2.1	0.86	1.0	0.99	1.9	1.2
	Nb-95	5.2	1.5	1.7	1.6	4.1	2.3
	Ru-103	0.19	0.046	0.017	0.12	0.75	0.33
	Ru-106			0.060			0.058
	Ag-110m		0.050	0.45	0.75	1.4	0.41
	Cd-109		0.49	0.42	0.45	0.39	0.11
	Sb-122		0.0051	0.0095	0.0053		
	Sb-124			0.055	0.00045		0.0065
	I-130						
	I-131	0.045	4.1	0.088	3.9	28	0.31
	I-132						
	I-133		0.0033		0.0017		
	I-134						
	I-135						
	Cs-134	8.4	4.6	4.6	2.2	1.5	1.4
	Cs-137	55	67	74	46	40	31
	Ba-140					0.023	
	La-140		0.0053		0.053	0.077	
	Ce-141	0.25	0.062	0.076	0.20	0.58	0.29
	Ce-144	5.1	0.61	0.24	0.23	0.79	1.8
	Hf-175	0.023	0.065	0.033			
	Hf-181	0.14	0.30	0.35			
	Ir-192	0.063	1.9				

3.2.4 Emissions to air

Table 3.2 Annual emissions of ^{3}H from IFE-Halden 2012-2017.

	2012 TBq	2013 TBq	2014 TBq	2015 TBq	2016 TBq	2017 TBq
Emission of tritium to the atmosphere	19	27	19	27	26	23

The release of I-129 to the atmosphere has been estimated to 0.2 Bq/year. The emission of C-14 has not been estimated.

3.2.5 Systems for quality assurance

The automatic closing function of the main outlet valves on the discharge line from containment and from delay tank, which is initiated by abnormally high activity levels, is tested along with other instrumentation before each reactor start up.

The conductivity of water leaving ion exchange columns is measured continuously in order to monitor the ion exchange efficiency of the resin. To further monitor the function of the ion exchange columns, gamma spectrum analysis is performed on samples taken periodically of water entering and leaving the columns.

Continual logging of all instrument signals performed by the process data collection and presentation system. Live time data and historical data can be graphically displayed and trends can be detected.

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.

In 2011, IFE was certified to the ISO 9001 and ISO 14001 standards. Whereas the ISO9001 involves standard for quality management systems, the ISO 14001 is a standard for environmental management.

3.2.6 Site specific target discharge values

Discharge levels are related primarily to the radionuclide specific discharge limits given by the authorities. In addition the release is controlled based on a target of not more than one tenth of the limiting resulting doses to the critical group. Based on the target and discharge statistics (historical releases), every discharge source is controlled by reference levels expressed as MBq/m^3 for each radionuclide.

Through the authorisation conditions for release of radioactive substances, the operator is obliged to limit the discharge to levels as low as reasonable achievable (ALARA) and use of best available technology (BAT) in order to achieve this. Equipment, methods and routines are continuously evaluated for potential discharge reducing measures, including measures to enhanced worker awareness of the issue. In any effort to reduce discharges, the resulting discharge reduction are considered, among other things, in view of doses incurred by occupationally exposed individuals and the economic investment necessary to achieve the reduction. Since the current discharge levels and resulting doses to the public are very low, evaluation of possible major new installations often reveal that the doses or investment involved in implementing additional measures do not justify the marginal reduction in discharge that could be achieved. The best dividends are often achieved through apparently modest changes to existing equipment or procedures, and in increased worker awareness.

3.2.7 Any relevant information not covered by the requirements specified above

Not relevant.

3.2.8 Explanations for lack of data or failure to meet BAT/BEP indicators, as well as, when appropriate, a description of on-going or planned activities.

There is no downward trend in discharges of liquid radioactive waste. 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 from June 2018. This will have an effect on the discharge in the future.

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.

3.2.9 Summary evaluation

Table 3.3 summarizes the evaluation of BAT/BEP for IFE Halden concerning discharge.

Table 3.3 summarizes the evaluation of BAT/BEP for IFE Halden concerning discharge.

Criteria	**Evaluation**
BAT/BEP indicator	
• Relevant systems in place	Yes
• Abatement factor	Normal for existing abatement systems
• Downward trend discharges	No downward trend, variation in liquid discharge is caused by variations in research activity
• Downward trend discharge normalized	Not applicable
• Downward trend emission	No downward trend, variation in emission is caused by variations in research activity
• Relevant and reliable QA systems	Yes
• Relevant site specific target values	Target values not implemented
Data completeness	Complete
Causes for deviations from indicators	See text section 3.2.8
Uncertainties	No impact on the conclusions
Other information	None

3.3 Environmental impact

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

Table 3.4 shows the average concentration of Cs-137 in shore sand and fish samples collected in Iddefjord and sediment and water samples from the river Tista, above and below the discharge point from the reactor site. From 2016 river water samples have also been taken from a third location, up-stream from the discharge point from the reactor, but downstream from the release from the adjacent paper mill.

Table 3.4. Average concentration of Cs-137 in shore sand from beaches in Iddefjord, fish from Iddefjord (average from 2 locations), and sediment and water from upstream and downstream of the discharge area in the river Tista (average of 4 samples; 2 samples in spring and 2 in autumn)

	Shore sand (4 beaches) (Bg/kg)	Fish samples (Bq/kg)	River sediment upstream (Bq/kg)	River sediment down-stream (Bq/kg)	River water upstream both paper mill and reactor (Bq/kg)	River water downstream paper mill and upstream reactor (Bq/kg)	River water downstream both paper mill and reactor (Bq/kg)
2012	2.7	0.7	32	22	0.0009		0.0014
2013	1.9	1.1	29	21	0.0009		0.0013
2014	2.0	0.8	23	19	0.0009		0.0037
2015	2.1	0.8	20	19	0.0009		0.0018
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

3.3.2 Environmental monitoring programme, frequency of sampling, organisms

The environmental monitoring programme includes:

- Bottom sediment from two locations in the river Tista, twice a year
- Bottom sediment from previous discharge area in the river Tista, once a year.
- Sediment samples from sand beaches along the fjord, once a year
- Fish from two locations in Iddefjord, once a year
- Grass from neighbouring farms, twice a year
- Precipitant (rain, snow) from two locations once a fortnight
- Water from two locations in the river Tista, twice a year. Increased to three locations from 2016

3.3.3 Systems for quality assurance of environmental monitoring program

In 2011, IFE was certified to the ISO 9001 and ISO 14001 standards. Whereas the ISO9001 involves standard for quality management systems, the ISO 14001 is a standard for environmental management.

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.

3.3.4 Any relevant information not covered by the requirements specified above

Not relevant.

3.3.5 Explanations for lack of data or failure to meet BAT/BEP indicators, as well as, when appropriate, a description of on-going or planned activities

The measured activities of anthropogenic nuclides in the environmental samples are very low and also include a significant background from the Chernobyl fallout. Therefore, the BAT/BET indicators are considered being met even though no downward trend is observable.

3.3.6 Summary evaluation

Table 3.5 summarizes the evaluation of BAT/BEP for IFE-Halden concerning environmental impact.

Table 3.5 summarizes the evaluation of BAT/BEP for IFE-Halden concerning environmental impact.

Criteria	**Evaluation**
BAT/BEP indicator	
• Downward trend in concentrations	Low concentrations, but no downward trend
• Relevant monitoring program	Yes
• Relevant and reliable QA system	Yes
Data completeness	Complete
Causes for deviations from indicators	See text in section 3.3.5
Uncertainties	No impact on the conclusions
Other information	None

3.4 Radiation doses to the public

3.4.1 Average annual effective dose to individuals within the critical group

Average annual effective dose to individuals within the critical group from liquid discharges from HBWR is shown in table 3.6.

Table 3.6 Annual effective dose from liquid discharges to individuals within the critical group from 2012-2017.

	2012	2013	2014	2015	2016	2017
Annual effective dose (µSv)	0.008	0.005	0.002	0.002	0.002	0.001

3.4.2 Total exposures

The total exposure from both liquid discharges and releases to the atmosphere, assuming that the same individuals are in the critical group for both exposure pathways, are dominated by the doses from releases to the atmosphere. The annual effective doses are shown in table 3.7.

Table 3.7. Annual effective dose from liquid discharges and emission to the atmosphere to individuals in the critical group from 2012-2017

	2012	2013	2014	2015	2016	2017
Annual effective dose (µSv)	2.5	3.9	1.8	2.3	3.0	2.0

3.4.3 The definition of the critical group(s)

The critical group is hypothetical and defined by their food consumption and living habits. The estimation of doses to the group is based on theoretical radionuclide concentration in the environment, calculated from discharge values. The dose represents an average in a group with an age distribution identical to the age distribution of the Norwegian population**.** It has been established that children, taking their consumption and living habits into account, do not receive doses which deviate significantly from the average.

3.4.4 Information on exposure pathway(s)

The calculation of effective dose to the critical group is based on:

- 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

3.4.5 Basis for methodology to estimate doses

All modelling of transfer of radionuclides in the environment and doses to critical groups are based on:

> 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)

3.4.6 Site-specific factors

No site specific factors are used. The estimates are based on default factors from the above reference, section 3.4.5.

3.4.7 Site specific target annual effective dose

The discharge limits defined by the authorities are based on a limiting annual effective dose of 1 µSv to individuals in the critical group. Target values are not implemented.

3.4.8 Systems for quality assurance of processes involved in dose estimates

There are no measurements involved in the dose assessments. The calculations have been tested by comparison with example calculations from the reference in section 3.4.5.

3.4.9 Any relevant information not covered by the requirements specified above

Not relevant.

3.4.10 Explanations for lack of data or failure to meet BAT/BEP indicators

A downward trend can be seen for doses from liquid discharges. This is a consequence of the variations in the research activities, as described in section 3.2.8.

3.4.11 Summary evaluation

Table 3.8 summarizes the evaluation of BAT/BEP for IFE Halden concerning radiation dose to the public

Table 3.8 Summary evaluation of radiation dose to the public.

Criteria	**Evaluation**
BAT/BEP indicator	
• Downward trend in radiation dose, critical groups	Low doses, but no downward trend. Caused by variations in the research activity and waste treatment
• Total exposure within the constraint	Yes
• Relevant critical groups	Yes
• Reliable dose estimates	Yes
• Relevance of target dose	Target dose not implemented
• Relevant and reliable QA system	Yes
• Data completeness	Yes

3.5 Summary BAT/BEP

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.

Appendix 1

System(s) in place to reduce, prevent or eliminate discharges and their efficiency IFE Kjeller

Abatement system/ Management	Into operation (Year)		Efficiency of abatement system		Comments
	Existing	Planned	Decontamination Factor	Other measure of efficiency	
Discharges:					
delay tank(s)	8		3	67 %	
Ion exchange	1		33	97 %	except ^{3}H
Evaporator	1		20	95 %	except ^{3}H
Emissions:					
HEPA filtration	many		50	98 %	see 2.2.2
Active charcoal filters	4		> 20	> 95 %	see 2.2.2
Changes in management or processes:					see 2.2.2

Appendix 2

System(s) in place to reduce, prevent or eliminate discharges and their efficiency IFE Halden

Abatement system/ Management	Into operation (Year)		Efficiency of abatement system		Comments
	Existing	Planned	Decontamination Factor	Other measure of efficiency	
Discharges:					
Sedimentation in delay tank(s)	1		1.02 – 1.25	2 – 20 %	see 3.2.2
Filtration and ion exchange from delay tank(s)	1		33	97 %	
Ion exchange	many		100	99 %	
Ion exchange form laundry tank	1 (2012)		10	90 %	
Sedimentation in laundry tank	1 (2012		1.1 – 1.7	8 – 40 %	
Evaporation	1		20	95 %	
Tritium trapping in He-3 system	1		10	90 %	
Emissions:					
HEPA filtration and active charcoal filtration	4		100	99 %	
Changes in management or processes:					

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