OSPAR
COMMISSION

Sixth Implementation Report:

Report in accordance with PARCOM Recommendation 91/4 on radioactive discharges

Norway

Radioactive Substances Series

2014

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

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.
La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l’Irlande, l’Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d’Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l’Espagne.

Acknowledgement

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Contents

Introduction

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).

1. General information

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

Since the last implementation round the Pollution Control Act 13 March 1981 on Protection against Pollution and Concerning Waste entered into force for radioactive pollution and radioactive waste on 1 January 2011. The act was established for the purpose of preventing and reducing harm and nuisance from pollution. This is reflected in the main rule of the act, which says that pollution is forbidden, unless it is specifically permitted by law, regulations or individual permits. The act shall 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
- Regulation on the Recycling of Waste of 1 June 2004
- Regulation on Pollution control of 1 June 2004

The regulation Radioactive Pollution 1 November 2010 defines radioactive pollution and radioactive waste.

The Regulation on the Recycling of Waste 1 June 2004 establishes requirements for waste in general, chapter 16 deals with radioactive waste.

The Regulation on Pollution control 1 June 2004 defines procedures for applications for permits and establishes administrative provision for radioactive pollution and waste.

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

When issuing authorisations for nuclear installations, Norwegian practice is to focus on BAT, ALARA-principle and the precautionary principle. Use of BAT regarding discharge of radioactive substances is implemented in 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 Dose constraints/limits for nuclear facilities

The dose limit applied in the current discharge authorisation given to each of the two sites of the Institute for Energy Technology is 1 µSv/year for the most exposed members of the general population from liquid discharges. The dose limit for emission to air is 100 µSv/year of which iodine isotopes shall not contribute more than 10 µSv/year.

1.3 Discharge limits

For the reporting period, the Norwegian Radiation Protection Authority (NRPA) has not defined radionuclide specific discharge limits for the nuclear facilities. Restrictions of discharge have been implemented through dose limit to the most exposed members of the general population. In addition to discharge limits, the NRPA have enforced nuclide specific notification levels. If a notification level is exceeded the operator must inform the NRPA, and the reason for the discharge must be explained.

After the implementation of the Pollution Control Act 13 March 1981 the NRPA issued permits with radionuclide specific discharge limits for the nuclear facilities on 20 December 2013. The radionuclide specific discharge limits are specific for each of the nuclear facilities and are based on the ALARA-principle, taking historical discharge data and planned changes in research activity into account, while complying with the dose limits.

1.4 Monitoring programmes of environmental concentrations of radionuclides

The operators of the research reactors are according to their discharge authorisations required to carry out environmental monitoring, 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 control 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 radioactive contamination on 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. The report for radioactivity in the marine environment for 2010 can be found at: http://www.nrpa.no/dav/3783b30ce2.pdf

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

Action limits for the concentration of Cs-137 and Cs-134 in foodstuffs exists, but in principle they apply in relation to Chernobyl-derived contamination only. Otherwise, the degree of protection of the environment still is based on the protection of human health through the application of dose constraints/limits.

Norway is in the process of developing regulations for radionuclides in foodstuffs, feedstock and drinking water for use in emergency situations, and for natural radioactivity in drinking water.

Internationally accepted and agreed criteria for environmental protection are so far lacking, but the NRPA is engaged in activities of the International Union of Radioecology and the ICRP to develop a framework for the protection of the environment from ionizing radiation, and this work is expected to contribute to the development of environmental norms and standards.

1.6 National authority responsible for supervision of discharges

Licensing and supervision of the operation of nuclear sites is carried out by the NRPA.

1.7 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 annually reports from the Institute for Energy Technology on environmental monitoring and control 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. Licence for operation of facility e) is not required according to the Nuclear Energy Act 12 May 1972.

A production line for the new radiopharmaceutical product Xofigo has been planned, built and tested during the reporting period. The production line was inaugurated on 20 June 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. From this facility it is discharged to the river Nitelva about 100 km from the sea. The river, having an annual mean flow of 5 m^3/ second leads into Lake Øyern where the water is mixed with the water of river Glomma having an annual mean flow of 400 m^3/second. Glomma river empties into the Oslo Fjord, having 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 waste disposal and storage.

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 discharges.

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 Norwegian Radiation Protection Authority (NRPA). 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 waste are retained in tanks at the production facilities before pumped over to the Radioactive Waste Treatment Plant for further treatment by evaporation, filtration in ion exchange systems or retention in large storage tanks for decay. The short lived radionuclides are normally allowed to decay to a very low level before discharges if sufficient tank capacity is available.

Relevant systems in place (appendix 1) are:

- Storage to reduce the level of radioactivity of short lived nuclides
- Ion exchange filtration
- Vacuum evaporation system

Before discharges are authorised by IFE's Health and Safety Department measurements of the activity levels of gamma emitting radionuclides and tritium are performed. Discharges are authorised if the restriction of annual doses to members in critical groups is fulfilled by the annual accumulated discharges. 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 and the results are reported.

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 must, however, be seen in view of doses incurred by occupational 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 a measure do not justify the marginal reduction in discharge that is possible to achieve. The best dividends are often achieved through apparently modest changes to existing equipment or procedures, and in increased worker awareness.

In 2010 IFE Kjeller implemented improved routines for authorising liquid discharges. The routines are now as follows:

- Liquid waste water that will lead to a dose of more than 1 μSv to members of the critical group shall not be discharged to the river Nitelva. Radioactive components must be removed from the waste water prior to discharge. Choice of abatement system will depend on which radionuclides are present and the efficiencies of the different systems;
- Liquid waste water that will lead to a dose of 0.2-1 μSv to members of the critical group will be treated by one of the available abatements systems after a consideration of ALARA and possible additional doses to workers at IFE involved in the waste water treatment;
- Liquid waste water that will lead to a dose of less than 0.2 μSv to members of the critical group will be discharged to the river Nitelva without further treatment.

For all categories, discharge history for the current year is taken into account to ensure that the accumulated discharge does not increase the limit given by the NRPA.

Also, improved control that waste water volumes pumped through the NALFA pipeline reaches the river Nitelva, has been implemented. The waste water flow through the NALFA pipeline is controlled by measuring the flow at the start and end of the pipeline. The old system was sensitive to particles and fibers, and now and then discharges had to be stopped due to different readings. The new system eliminates this problem.

For emissions to the air the NRPA has authorised a discharge limited of an annual dose of 100 µSv to members in a critical group in the population in the proximity of IFE. Additional restriction in the emission of iodine isotopes is that this should be 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 will be achieved.

During the last six years some changes in the environmental monitoring program has been introduced to improve monitoring efficiency.

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.

Treatment of waste water was prohibited in 2008 by the head of radiation protection at IFE Kjeller, based on the increasing doses to workers at the Radioactive Waste Treatment Plant from this treatment.

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. 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 2007-2012 are given in table 2.1.

Table 2.1 Annual liquid discharges from IFE-Kjeller 2007-2012

Radio-nuclides	2007 (MBq)	2008 (MBq)	2009 (MBq)	2010 (MBq)	2011 (MBq)	2012 * (MBq)
^{3}H	499 000	1 690 000	400	4070	29 400	0
^{90}Sr	0.50	12.2	0.356	0.142	4.53	0
^{134}Cs	0.5	4.10	< 0.04	0.37	< 0.05	0
^{137}Cs	9.5	32.1	0.398	2.82	1.44	0
^{125}I	44.1	44.9	25.0	< 0.2	< 0.3	0
^{131}I	2.0	1.26	0.00545	< 0.001	< 0.008	0
^{60}Co	71.7	33.1	1.56	1.10	3.25	0
^{54}Mn	< 0.3	< 0.2	< 0.03	< 0.02	< 0.05	0
^{65}Zn	< 0.7	2.75	< 0.07	< 0.1	0.046	0
$^{239, 240}$Pu	0.07	7.65	0.0141	0.0360	0.471	0
^{238}Pu	0.002	0.0469	0.000111	0.000317	0.0055	0
^{241}Am	0.007	0.907	0.00221	0.00581	0.018	0
^{51}Cr	< 0.5	< 1.7	< 0.04	< 0.07	< 0.3	0
^{59}Fe	< 0.3	< 0.5	< 0.03	< 0.04	< 0.08	0
^{58}Co	< 0.2	< 0.2	< 0.02	< 0.02	< 0.05	0
^{103}Ru	< 0.1	< 0.2	< 0.01	< 0.02	< 0.04	0
^{106}Ru	< 2.0	< 1.7	< 0.3	< 0.3	< 0.4	0
^{124}Sb	< 0.2	< 0.2	< 0.02	< 0.02	< 0.04	0
^{125}Sb	< 0.7	< 0.6	< 0.2	< 0.2	< 0.2	0
^{144}Ce	< 1.3	0.383	< 0.2	< 0.08	< 0.3	0
^{110m}Ag	0.05	< 0.2	< 0.04	< 0.03	< 0.04	0
^{95}Zr	< 0.2	< 0.4	< 0.02	< 0.04	< 0.07	0
^{95}Nb	< 0.1	< 0.2	< 0.01	< 0.01	< 0.04	0
^{234}U	0.0024	0.879	0.00302	0.0330	0.0245	0
^{235}U	0.000025	0.0346	0.0000899	0.00137	0.00104	0
^{238}U	0.0018	0.924	0.00291	0.0331	0.0228	0
^{244}Cm	0.0019	0.000216	0.000173	0.000349	0.00315	0
^{22}Na	0.56	< 0.2	< 0.03	< 0.02	< 0.06	0
^{133}Ba	-	-	-	-	0.149	0

* 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 2007-2012.

	2007	2008	2009	2010	2011	2012
% of limit	9.4	30.4	0.53	2.52	1.23	0

The discharge in 2008 of 30.4 % of the limit was caused by enhanced levels of ^{3}H, ^{60}Co and ^{137}Cs in wastewater from treatment of ion-exchange resins. Further treatment of this waste water was prohibited by the head of radiation protection at IFE Kjeller, based on the increasing doses to workers at the Radioactive Waste Treatment Plant from this treatment.

There is no downward trend in discharges of liquid radioactive waste.

2.2.4 Emissions to air

The only emission to air of nuclides with half-lives exceeding 30 days form the facilities at IFE, Kjeller, is ^{3}H from operation of the JEEP II research reactor, sometimes traces of ^{137}Cs in emissions form the hot cell laboratories, and until 2009 small amounts of ^{125}I from the radiopharmaceutical production facility. Tables 2.3 show the activity in the annual emissions. The decrease in emissions of I-125 to air between 2008 and 2009 is due to the fact that GE Healthcare closed their pharmaceutical production facility at IFE Kjeller's premises.

Table 2.3 Annual emission of ^{3}H, ^{125}I and ^{137}Cs from IFE-Kjeller 2007-2012

Nuclide	2007 (GBq)	2008 (GBq)	2009 (GBq)	2010 (GBq)	2011 (GBq)	2012 (GBq)
^{3}H	4200	4400	6120	5601	5522	6329
^{125}I	0.029	0.038	0.0007	0	0	0
^{134,137}Cs			0	0.0002	0	0

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 in relation to the technical condition of the pipeline, procedures to verify that discharges actually reach the discharge point in Nitelva river and control of the water level in the river prior to discharge has been implemented.

Prior to discharges IFE's internal Health and Safety Department has measured the nuclide content and activity levels in the waste water and authorised discharge if the restriction of annual dose to members in the critical group is fulfilled by the annual accumulated discharges. 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 outdoor air are every three months reported to IFE's board of directors and yearly in a report to NRPA.

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.

2.2.6 Site specific target discharge values

Discharges of liquid radioactive waste 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. The increase of discharges in 2008 is due to increased levels of ^{137}Cs and ^{3}H in water from treatment of ion exchange resins.

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

Table 2.5 Summary evaluation of discharges from IFE Kjeller.

Criteria	**Evaluation**
BAT/BEP indicator	
• Relevant systems in place	Yes
• Abatement factor	Normal for existing abetment 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. Decrease between 2008 and 2009 due to shut down of GE Healthcare's pharmaceutical production facility.
• 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 2.6 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 2.6 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
2007	4.6 (3)	0.046 (1)	4.8 (3)	0.051 (2)	5.1 (3)	0.044 (1)
2008	4.7 (3)	- (0)	4.7 (3)	- (0)	3.3 (3)	0.037 (1)
2009	4.8 (3)	- (0)	5.3 (3)	- (0)	4.7 (3)	- (0)
2010	4.0 (3)	- (0)	4.2 (3)	0.13 (1)	5.0 (3)	0.11 (1)
2011	4.1 (3)	0.036 (1)	4.3 (3)	- (0)	4.6 (3)	- (0)
2012	4.7 (3)	0.11 (1)	4.1 (3)	- (0)	4.6 (3)	- (0)

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

Table 2.7 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 2.7 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	^{40}K	^{137}Cs	^{239,240}Pu	U_{nat}	^{90}Sr
2007	827 ± 97	40 ± 2	0.6 ± 0.2	89 ± 3	1.9 ± 0.6
2008	940 ± 40	57.9 ± 2.3	0.12 ± 0.07	99 ± 7	0.9 ± 0.4
2009	1020 ± 50	≤ 1.3	≤ 0.04	58 ± 8	≤ 1.3
2010	890 ± 50	46.4 ± 2.3	0.26 ± 0.09	143 ± 17	1.1 ± 0.3
2011	760 ± 40	31.9 ± 1.3	0.20 ± 0.07	104 ± 13	1.0 ± 0.5
2012	470 ± 30	7.9 ± 0.7	0.10 ± 0.06	43 ± 6	1.12 ± 0.24
SD 4	^{40}K	^{137}Cs	^{239,240}Pu	U_{nat}	^{90}Sr
2007	898 ± 48	77 ± 3	21.0 ± 1.6	143 ± 11	2.0 ± 0.4
2008	880 ± 40	51.6 ± 1.9	14.1 ± 1.1	112 ± 7	1.17 ± 0.23
2009	810 ± 40	31.9 ± 1.5	34.8 ± 1.8	108 ± 13	1.4 ± 0.4
2010	960 ± 50	52.4 ± 1.9	44 ± 12	129 ± 17	1.3 ± 0.3

2011	810 ± 40	66.5 ± 2.8	46 ± 6	100 ± 13	1.11 ± 0.23
2012	560 ± 50	27.8 ± 2.1	3.2 ± 0.8	93 ± 12	1.4 ± 0.4
SD 5	^{40}K	^{137}Cs	^{239,240}Pu	U_{nat}	^{90}Sr
2007	842 ± 30	53 ± 2	5.5 ± 0.6	129 ± 8	1.9 ± 0.3
2008	840 ± 40	44.1 ± 1.8	28 ± 4	121 ± 9	1.9 ± 0.4
2009	910 ± 50	68.6 ± 2.8	52.6 ± 2.7	98 ± 11	0.9 ± 0.3
2010	820 ± 50	51.8 ± 2.4	8.7 ± 1.6	107 ± 14	1.4 ± 0.3
2011	820 ± 40	9.1 ± 0.6	1.11 ± 0.23	67 ± 9	0.87 ± 0.25
2012	780 ± 50	6.0 ± 0.7	1.2 ± 0.4	83 ± 11	0.56 ± 0.30

Table 2.8 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 2.8 Concentrations in Bq/kg of radionuclides in fish of all types. The results are for wet weight samples

Year*	^{40}K	^{137}Cs **	^{239,240}Pu **	^{90}Sr
2007 (6)	177 ± 18	3.9 ± 0.8 (4)	0.0018 ± 0.0007 (1)	0.28 ± 0.09
2008 (4)	126 ± 11	2.4 ± 1.9	0.0013 ± 0.0011 (1)	0.18 ± 0.27
2009 (6)	128 ± 18	1.9 ± 2.6	0.0022 ± 0.0026 (2)	0.10 ± 0.08
2010 (3)	131 ±18	2.5 ± 3.3	- (0)	0.095 ± 0.095
2011 (6)	122 ± 23	1.6 ± 2.2	0.0017 ± 0.0006 (1)	0.14 ± 0.17
2012 (4)	104 ± 16	2.6 ± 4.7	0.016 ± 0.003 (1)	1.1 ± 1.8

* 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 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'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 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 IFE 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 back to discharges in the 1960-ies and 1970-ties and is residues after clean-up of sediments in the riverbed in 2000-2001.

2.3.6 Summary evaluation

Table 2.9 summarizes the evaluation of BAT/BEP for IFE Kjeller concerning environmental impact.

Table 2.9 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 2.10.

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

	2007	2008	2009	2010	2011	2012
µSv to critical group	0.09	0.30	0.0053	0.0252	0.0123	0

Average annual effective doses to individuals in the critical group from emission to outdoor air IFE-Kjeller are given in table 2.11:

Tabel 2.11 Average annual effective doses to individuals in the critical group from emission to outdoor air IFE-Kjeller

	2007	2008	2009	2010	2011	2012
µSv to critical group	3.7	4.1	2.0	1.78	2.03	2.34

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 outdoor air 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 only 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, does not receive doses that deviate significantly from adults. In calculation of the collective doses from discharges of liquid waste the population in all the municipalities around the lake Øyern, *i.e*. Skedsmo, Fet, Rælingen, Trøgstad and Spydeberg are included. The total population was 83 811 people in 2010. The age distribution is given in table 2.12.

Table 2.12 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 air 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 2.13 summarizes the evaluation of BAT/BEP for IFE Kjeller concerning radiation dose to the public.

Table 2.13 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 31/12-2014

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/sec. The volume of Iddefjord is $4 \cdot 10^8$ m^3, the average outflow to Skagerrak is 180 m^3/sec and average inflow from Skagerak is 150 m^3/sec.

3.1.6 Production

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

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 from the mountain hall. The water is slightly contaminated, primarily with tritium, and is lead 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.

In 2010, a new discharge tank was installed for the collection of water from drain and dishwasher in the chemistry laboratory in order to obtain better control of discharge. After control of activity, the water is discharged. If the activity exceeds a predefined level, the water is cleaned by ion exchange filtration.

A new system for treating water from the plant laundry was installed in 2013. Previously, the water was discharged through the delay tank, as described above. Due to the detergent content in the water, purification by ion exchange or evaporation is difficult. However, a study of purifying laundry water performed at the HWBR shows that activity can be efficiently reduced by ion exchange filtration. A new collection tank with a sludge interceptor and particle filters for laundry water has been installed with the purpose of improved control of discharge and the possibility and simplification of water purification in cases of abnormal activity levels. The activity is measured before discharge and the water is purified by ion exchange filtration if the activity exceeds a predefined level.

Ion exchange and evaporation

Discharges from the experimental circuits are multiple cycled through filters and ion exchange columns and the activity is close to zero before it is discharged. Liquid discharges from the laboratories are evaporated to a collection tank and discharged after control 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, a particular type of 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 new laundry water system, a separate tank for sludge sedimentation is 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 are 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 2007-2012 are given in table 3.1.

Table 3.1 Annual liquid discharges from IFE-Halden 2007-2012

SITE	**Radio-nuclides**	**2007 MBq**	**2008 MBq**	**2009 MBq**	**2010 MBq**	**2011 MBq**	**2012 MBq**
Institute for Energy Technology Halden Boiling Water Reactor	H-3	9.8E+6	2.2E+6	1.8E+6	1.1E+7	1.4E+6	8.5E+5
	Cr-51	33	30	43	21	18	12
	Mn-54	0.55	0.98	0.45	0.63	1.1	0.2
	Fe-59	0.71	2.8	0.44	1.2	0.25	0.29
	Co-58	4.7	18	3.9	5.2	2.0	1.2
	Co-60	62	46	40	41	48	33
	Zn-65	0.008				112	0.04
	Sr-90	6.8	5.2	1.0	1.8	1.8	5.7
	Zr-95	6.1	5.8	3.9	2.7	4.4	2.1
	Nb-95	16	11	9.0	5.3	11	5.2
	Ru-103	1.1	1.9	0.37	0.54	0.32	0.19
	Cd-109	0.13	0.024		0.34		
	Ag-110m	4.2	2.2	2.1	0.96	0.74	
	Sb-124						
	Sb-125	0.023	0.007	0.025			
	I-130					0.017	
	I-131	2.4	25	2.4	5.6	8.5	0.045
	I-132				0.13	2.2	
	I-133				5.8	7.3	
	I-134					12	
	I-135				0.71	11	
	Cs-134	36	39	8.1	4.8	13	8.4
	Cs-137	295	257	91	64	81	55
	La-140			0.89		0.021	
	Ba-140			0.13		0.013	
	Ce-141	1.9	1.9	0.57	0.25	0.76	0.25
	Ce-144	22	22	4.9	7.5	9.3	0.25
	Hf-175						0.023
	Hf-181						0.14
	Ir-192						0.063

The increases of discharges of H-3 and iodine isotopes in 2010 and 2011 is due to contamination in connection to episodes with fuel failure and an incident with breach in a cooler in an experimental loop.

3.2.4 Emissions to air

Table 3.2 Annual emissions of ^{3}H from IFE-Halden 2007-2012.

	2007 TBq	2008 TBq	2009 TBq	2010 TBq	2011 TBq	2012 TBq
Emission of tritium to the atmosphere	51	55	70	50	28	19

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 follow 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 is taken care of 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 discharge limits given by the authorities.

In addition to discharge limits which are directly related to resulting doses to the critical group, the authorities have enforced nuclide specific notification levels. These levels are related to previous operational results at the facility. If a notification level is exceeded, the authorities must be informed and the reason for the discharge explained.

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 enhanced worker awareness of the issue. In any effort to reduce discharges, the resulting discharge reduction must, however, be seen in view of doses incurred by occupational 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 a measure do not justify the marginal reduction in discharge that is possible to achieve. 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.

There has been an increase in discharge of atypical nuclides from the plant laundry (eg. Zn-65, Hf-175, Hf-181 and Ir-192). Research involving irradiation of new materials has resulted in some episodes where contamination on work clothes has been discharged through the laundry water. New laundry routines including the installation of the new laundry water system (section 3.2.1) is expected to reduce the discharge of abnormal activity levels in laundry water.

The increases of discharges of H-3 and iodine isotopes in 2010 and 2011 is due to contamination in connection to episodes with fuel failure and an incident with breach in a cooler in an experimental loop.

3.2.9 Summary evaluation

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

Table 3.3 Summary evaluation of discharge from IFE Halden.

Criteria	**Evaluation**
BAT/BEP indicator	
• Relevant systems in place	Yes
• Abatement factor	Normal for existing abetment 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 (2 locations). A new discharge pipe line with a new discharge point was installed in Tista in 2006. No sedimentation occurs at the new point and the environmental monitoring program was adjusted in 2009/10 for additional sediment and river water samples. The program for river water was again changed in 2012 for increased sensitivity.

The Cs-137 activity concentrations in shore sand, fish, sediment and water are shown in table 3.4.

Table 3.4 Average concentration of Cs-137 in shore sand from beaches in Iddefjord, fish from Iddefjord, and sediment and water from upstream and downstream of the discharge area in the river Tista

	Shore sand (4 beaches) (Bg/kg)	Fish samples (Bq/kg)	River sediment upstream (Bq/kg)	River sediment downstream (Bq/kg)	River water upstream (Bq/kg)	River water downstream (Bq/kg)
2007	3.9	1.4				
2008	3.5	1.6				
2009	2.8	0.7			-	0.05[a]
2010	2.6	1.3[b]	58	16	-	-
2011	2.5	1.1[b]	48	38	-	-
2012	2.7	0.7[b]	32	22	0.0009	0.0014

[a] Non-filtered samples, [b]average of two locations

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.

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 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 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 2007-2012.

	2007	**2008**	**2009**	**2010**	**2011**	**2012**
Annual effective dose (μSv)	0.017	0.016	0.011	0.012	0.017	0.008

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 totally 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 2007-2012

	2007	2008	2009	2010	2011	2012
Annual effective dose (µSv)	6.4	7.3	8.1	6.2	3.7	2.5

The drop in dose after 2009 is a result of variations in the release to the atmosphere caused by variations in research activity.

3.4.3 The definition of the critical group(s)

The critical group is hypothetical and only 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

There are no downward trends for doses from liquid discharges. Variations in the discharges and the corresponding doses are primarily caused by variation 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 ^3H
Evaporator	1		20	95 %	except ^3H
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:					

OSPAR COMMISSION

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

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

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