OSPAR COMMISSION

Protecting and conserving the North-East Atlantic and its resources

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

Radioactive Substances Series

2019

Seventh Implementation Report

Issued in Accordance with the PARCOM Recommendation 91/4 on Radioactive Discharges

Presented by Switzerland

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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 Union 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 l’Union européenne et l’Espagne.

Contents

Executive Summary

PARCOM Recommendation 91/4 concerns the use of Best Available Technologies (BAT) to minimise and, as appropriate, eliminate any pollution caused by radioactive discharges from all nuclear industries, including research reactors and reprocessing plants, into the marine environment. According to Guidelines for the Submission of Information about, and the Assessment of, the Application of BAT in Nuclear Facilities (OSPAR agreement 2004-03) the Contracting parties shall present a statement on progress made in applying such technology every four years in accordance with the guidelines annexed to this recommendation.

This seventh implementation report provides an update on the use of BAT during 2016-2019. As in the previous rounds of reporting, Switzerland concludes that the BAT principles are implemented in the Swiss legislation and regulatory practice. Furthermore the report shows that progress has been made in the application of these principles. The overall liquid radioactive discharges from Swiss nuclear installations, comprising four nuclear power plants, an interim storage facility and a research facility, were reduced approximately by a factor of 10 over the last ten years.

Récapitulatif

La Recommandation PARCOM 91/4 concerne le recours à la meilleure technologie disponible, ou BAT, afin de minimiser et, s'il y a lieu, d'éliminer toute pollution causée par les rejets radioactifs, dans le milieu marin, de l'ensemble des industries nucléaires y compris les réacteurs de recherche et les usines de retraitement. Selon les Lignes directrices OSPAR relatives à la communication des informations sur, et à l'appréciation de l'application de la BAT dans les installations nucléaires (Accord OSPAR 2004-03), les Parties contractantes présenteront un état d'avancement de l'application de telles technologies tous les quatre ans.

Le présent rapport sur la septième mise en œuvre présente une actualisation de l'application de la BAT de 2016 à 2019. La Suisse a conclu, comme dans le cas des séries précédentes de notification, que les principes de BAT sont mis en œuvre dans le cadre de la législation et de la pratique réglementaire suisses. Ce rapport révèle de plus la progression de l'application de ces principes. Dans l'ensemble, les rejets radioactifs liquides provenant des installations nucléaires suisses, comprenant quatre centrales nucléaires, une installation de stockage provisoire et une installation de recherche, ont diminué d'environ 10% au cours de dix dernières années.

Introduction

This report relates to the seventh round of implementation reporting on PARCOM Recommendation 91/4 under which Switzerland was scheduled to report to OSPAR Radioactive Substances Committee in the year 2019. The report was produced on the basis of the OSPAR guidelines for the submission of information about the application of the best available technologies in nuclear facilities.

In first instance the OSPAR guidelines ask for general information on the national implementation of the Best Available Technology (BAT) / Best Environmental Practice (BEP) principles, discharge limits and monitoring programs. This information is provided in the next chapter. The subsequent chapters 1 to 4 give an overview of site characteristics, discharges, environmental impact, and radiation doses to the public due to the nuclear facilities in Switzerland. This overview documents the relevant changes during the reporting period and in chapter 5 a self assessment is given.

Detailed information and data on each of the four Swiss nuclear power plants, the waste treatment and interim storage facility ZWILAG and the Paul Scherrer Institute research facilities are given in the Annexes A to F with subsections enumerated according to the OSPAR guidelines.

General Information

In this chapter general information on the national implementation of the Best Available Technology (BAT) / Best Environmental Practice (BEP) principles, discharge limits and monitoring programs is provided.

Implementation of BAT/BEP in terms of the OSPAR Convention in national legislation

The Radiological Protection Act and the Radiological Protection Ordinance form the legal basis for the radiation protection in Switzerland. This legislation aims at protecting human health and the environment against ionising radiation and is based on the recommendations of the International Commission on Radiological Protection (ICRP). It implements the internationally agreed principles of justification of a practice, optimisation of radiation exposure and dose limitation. More detailed requirements are defined in further Ordinances and in Inspectorate's guidelines (www.ensi.ch). Further, specific conditions and obligations are contained in the operation licences granted to each nuclear facility operator.

In 2000 the ordinance for ratification of international resolution and recommendations came into force. This legislation requires that the PARCOM-recommendation 91/4 has to be taken into account when applying environmental protection regulations.

In 2005 a new nuclear energy legislation came into force. The new legislation requires the performance of periodic safety reviews by the licensee of nuclear power plants in a time interval of ten years. The periodic safety reviews are evaluated by the Nuclear Safety Inspectorate. In the frame of the periodic safety review the licensee has to assess the liquid and gaseous discharges of his plant and, at the request of the Inspectorate, to benchmark against the corresponding discharges of similar European reactors. If the discharges of a nuclear power plant are higher than the benchmark, the licensee has to analyze the reasons for these and to make suggestions to reduce the discharges with a view of the appropriateness of the proposed means.

In this context the BAT/BEP is implemented in the Swiss national legislation according to the terms of the OSPAR Convention. Further details are given in the Inspectorate's guidelines discussed below.

On the 1st of January 2018 a completely revised Radiation Protection Ordinance entered into force. The revision was done to obtain compatibility with the new European Safety Directive, Version 24th February 2010 (final) and the IAEA Basic safety Standard, Version July 2014.

Dose guide values / dose limits for nuclear facilities

The Ordinance on Radiological Protection sets the dose limit for members of the public at 1 mSv of annual effective dose. According to the Inspectorate's guideline G15 a source-related dose guide value is set for nuclear installations at 0.3 mSv per year and person as the sum of the doses due to radioactive emissions into the atmosphere, discharges into water and direct radiation. Furthermore the Inspectorate's guideline G15 sets a dose guide value for direct radiation at 0.1 mSv per year and person.

A nuclear facility has to be designed in such a way that the source-related dose guide values are not exceeded as a result of the radioactive releases caused by incidents with an occurrence probability greater than 0.01 per year and the dose limit for members of the public is not exceeded by incidents with an occurrence probability greater than 0.0001 per year.

Discharge limits

The discharge limits, as fixed in the license for operation of each facility, are set so that the source-related dose guide value of 0.3 mSv per year and person will not be exceeded. The dose calculation model for a person of the critical group in the vicinity of a nuclear facility is defined in the Inspectorate's guideline G14 of February 2008.

In the case of discharges into water, annual discharge limits are given for the releases of tritium and other nuclides. The radioactivity of nuclides with the exclusion of tritium is normalized with a reference immission limit value for waters of 10 Bq/l as a unit. A supplementary limit is set for the concentration of radioactivity in the discharged water: The concentration, calculated according to the summation rule with nuclide specific immission limit values for waters given in the Radiological Protection Ordinance, has to be lower than 2000 immission limit values for waters. In this document, non-normalized discharge data are reported.

Monitoring programs of radionuclide concentrations in the environment

For each facility the Swiss Federal Nuclear Safety Inspectorate (Inspectorate) has issued a set of discharge and environment monitoring regulations. These regulations contain the requirements on the control of discharges, as well as a complete program on environmental monitoring of radioactivity and direct radiation in the vicinity of the facility. The program is drawn up by the Federal Office of Public Health in co-operation with the Inspectorate, the National Emergency Operation Centre and the Cantons. It includes measurements of dose rate and integral dose, as well as samplings and measurements of air, drinking water, rainwater, river water, river sediments, soil, plants and food. The program is reviewed annually and modified as necessary.

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

The allowed concentration of radioactive substances released into the atmosphere and water is limited. The Radiological Protection Ordinance defines immission limits as weekly mean values of the concentration in waters accessible to the public. These immission limit values for waters are defined in the following way: A person covering its entire drinking water requirement with water contaminated to the level of the immission limit values would thereby receive an annual ingestion dose of 0.3 mSv.

The Swiss Ordinance on Contaminants defines the maximum concentration values for radionuclides in food and drinking water as an additional restriction. The maximum concentration values are based on the 10 microSv per year concept.

National authority responsible for supervision etc. of discharges

The Federal Office of Public Health is responsible for the environmental radiation supervision in Switzerland.

The Inspectorate is the national authority responsible for the supervision of emissions and discharges of radioactivity from nuclear facilities into air and water. In addition the Inspectorate monitors the ionizing radiation levels in the vicinity of nuclear installations.

Nature of inspection and surveillance programs

The Inspectorate's *regulations on radioactive discharges, monitoring of radioactivity and direct radiation in the vicinity of the nuclear facility* define the controlling of the emissions and discharges to be undertaken by the specific nuclear facility. It further states that samples and measurements are cross-checked between the Inspectorate, the Federal Office of Public Health and the nuclear facility at least 4 times per year. In addition, the Inspectorate performs inspections of abatement systems and environmental surveillance. All aspects of sampling, measurement (laboratories and equipment), data records, quality assurance and reporting are under review during these inspections. The mentioned regulations define the surveillance programs and establish the location, frequency and methods of sampling and measurement, as well as the responsibility for conducting the tests. The Inspectorate itself operates a remote dose rate monitoring system as part of the environment surveillance program.

1 Site Characteristics

In Switzerland there are four NPPs, a waste treatment and interim storage facility, one research facility and two facilities used for teaching purposes. The locations of the Swiss nuclear facilities are given in figure 1. All but one of the Swiss nuclear facilities discharge to the catchment area of the river Rhine, the exception being a nuclear facility for education purposes with no relevant discharges.

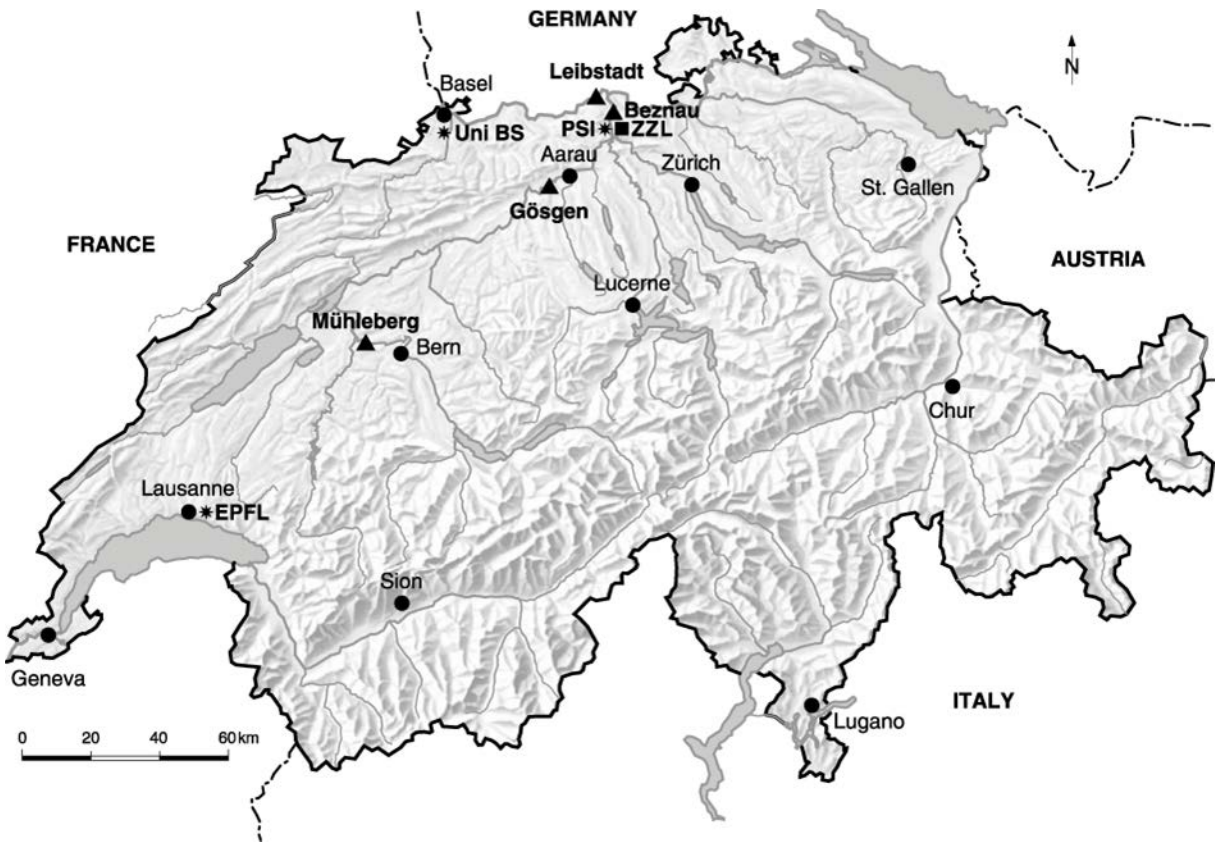

Figure 1: Location of the Swiss nuclear facilities. The sites of the NPPs are marked by triangles. Experimental and research installations are marked by stars. The nuclear waste treatment and interim storage facility is marked by a square. Dots mark the major cities.

Nuclear Power Plants

The names of the NPPs are Beznau, Gösgen, Leibstadt and Mühleberg. The Swiss NPPs are of four different reactor designs and were delivered by three different reactor suppliers. The main characteristics of the NPPs are compiled in table 1.

Table 1: Main characteristics of the Swiss NPPs

Name of site	**Beznau I**	**Beznau II**	**Mühleberg**	**Gösgen**	**Leibstadt**
Receiving waters	river Aare	river Aare	river Aare	river Aare, wet cooling tower	river Rhine, wet cooling tower
Licensed thermal power	1130 MW_{th}	1130 MW_{th}	1097 MW_{th}	3002 MW_{th}	3600 MW_{th}
Nominal net electrical power	365 MW_{el}	365 MW_{el}	373 MW_{el}	1010 MW_{el}	1220 MW_{el}
Reactor type / supplier[1]	PWR / W	PWR / W	BWR / GE	PWR / KWU	BWR / GE
Site Licence	1964	1967	1965	1972	1969
Construction Licence	1964	1967	1967	1973	1975
Commercial operation	1969	1971	1972	1979	1984
	First generation NPPs			**Second generation**	

Waste treatment and interim storage facility

The waste treatment and interim storage facility ZWILAG in Würenlingen was put in operation step by step. First, the interim storage facility started operation in 2001. The incineration and melting plant started operation with low-level radioactive waste in 2004 after several inactive tests. Since 2008 the facility processes practically any burnable and a part of the meltable waste from all Swiss nuclear facilities. In the years from 2001 to 2004 the emissions into the air and discharges into the river Aare were very low and are therefore not reported. Switzerland started reporting on ZWILAG to OSPAR in 2005.

Research facilities and facilities for nuclear education

The Paul Scherrer Institute (PSI) is part of the Domain of the Swiss Federal Institutes of Technology and is located between the villages of Villigen and Würenlingen in the North of Switzerland. The Paul Scherrer Institute is a multidisciplinary research institute for natural sciences and engineering. Various PSI laboratories handle radioactive materials. The institute hosts a federal radioactive waste treatment plant and the federal interim storage facility for radioactive waste resulting from industry, medicine and research. The treated waste waters of the Institute are discharged into the river Aare that belongs to the catchment area of the Rhine.

Three former research reactors and the Institute's experimental incineration plant are in decommission.

The facility for nuclear education at the University of Basel, for which decommissioning has been applied for, and the facility at the Ecole Polytechnique Fédérale de Lausanne (EPFL) have no relevant discharges and are therefore not reported in detail any further.

1 **W**estinghouse Co; **GE**neral Electric Co (now Global Nuclear Fuel); **KWU,** Kraftwerk-Union (now Framatome ANP); **BWR: B**oiling **W**ater **R**eactor; **PWR: P**ressurised **W**ater **R**eactor

2 Liquid Discharges

Detailed information and data on each of the four nuclear power plants, the waste treatment and interim storage facility and the research facility are given in the Annexes A to F in chapters enumerated according to the OSPAR guidelines for the site-specific information. In the following a summary is given.

Figure 2 presents the yearly discharges of radioactive substances excluding tritium from the nuclear facilities in Switzerland. The total sum of the discharges from all nuclear facilities shows a downward trend over the last 15 years.

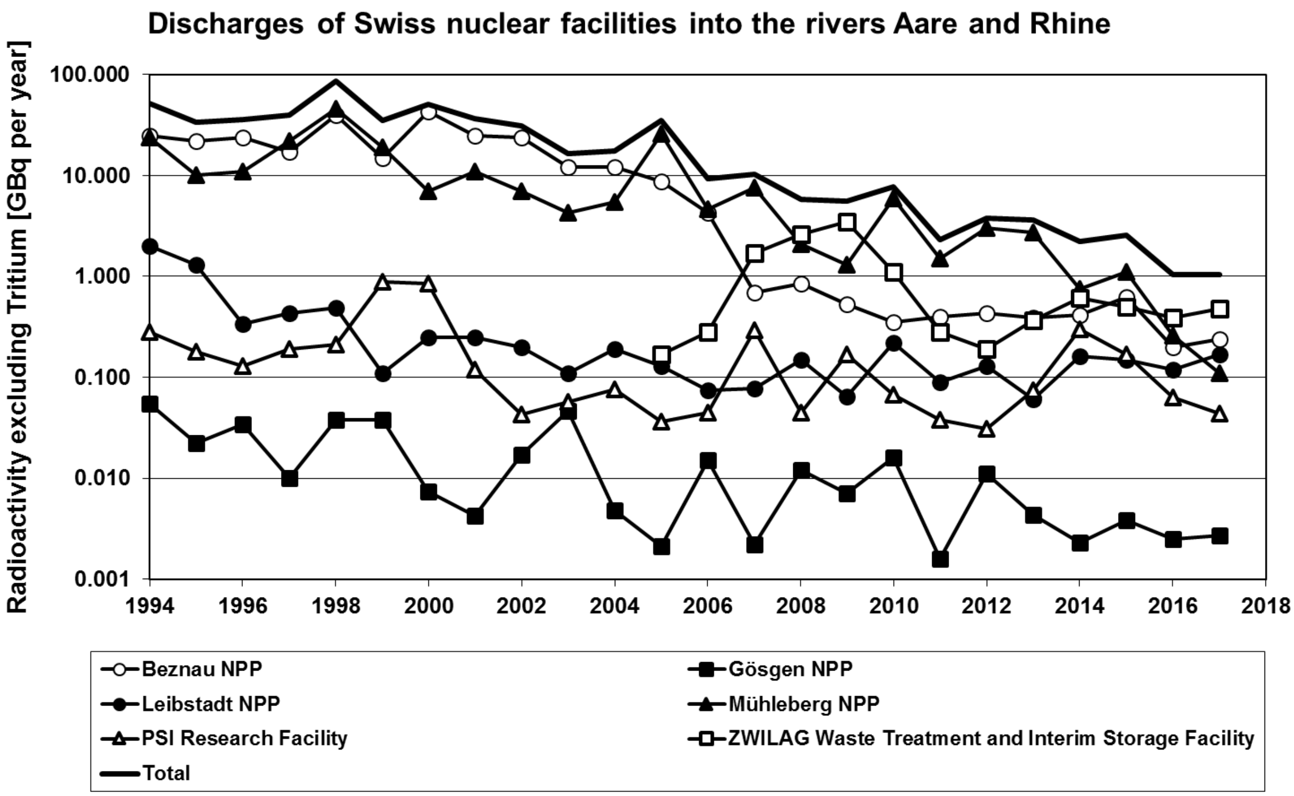

Figure 2: Discharges of radioactive substances by Swiss nuclear facilities 1994 to 2017: Beznau NPP, Gösgen NPP, Leibstadt NPP, Mühleberg NPP, PSI research facility, ZWILAG waste treatment and interim storage facility and the total sum of the discharges of all Swiss nuclear facilities.

Pressurized water reactors (PWRs)

When compared with the previous reporting period, the curve for Beznau NPP shows a clear downward trend. The licensee of Beznau had performed a periodical safety review for both units in 2002. The Inspectorate has evaluated this review and convinced the licensee of reducing the activity excluding tritium in the liquid discharges to less than the median value of the European pressurized water reactors of the year 2002. To reach this aim, the licensee of Beznau has started cleaning up the waste water by cross flow nanofiltration in 2007. The liquid discharges were reduced to below 1 GBq per year as a consequence.

The liquid discharges of Gösgen NPP are the lowest among the European pressurized water reactors. Nevertheless, the Gösgen NPP has further reduced discharges by a factor of 5 from 1994 up to now.

Boiling water reactors (BWRs)

The discharges of radioactive substances without tritium from the boiling water reactors at Leibstadt NPP and Mühleberg NPP show a downward trend. This is due to the optimization of the waste water management.

The licensee of Mühleberg has performed a periodical safety review in 2005. The Inspectorate has evaluated this review. As a result the Inspectorate requested from the licensee to reduce the activity excluding tritium in the liquid discharges to a target setting of 1 GBq per year by 2010. To reach this aim, the licensee studied possibilities for reducing the quantity of wastewater as well as separating different qualities of wastewater for a more specific treatment. Additionally in September 2015, the licensee has taken a small evaporator in operation. These measures have resulted in a decrease of the released activity from 7 GBq (2007) to 0.1 GBq (2017) per year.

Waste treatment and interim storage facility

The incineration and melting plant of the waste treatment and interim storage facility ZWILAG has started operation in 2005. Since then, the discharges of radioactive substances without tritium of this facility increased up to a value of 3.5 GBq in 2009 when the plasma incinerator reached its “fully operational” status, i.e. a balance between delivered and processed waste. In January 2009 the Inspectorate has required the licensee to study the possibilities to reduce the liquid discharges. As a result, the licensee started in 2010 to reduce the Cs-137 content in the liquid discharges by sorption with an inorganic ion exchange powder. Since the facility does not produce additional activities its discharges is directly correlated to both the amount and the characteristics of the processed waste, as long as the conditioning process remains unchanged.

Research facility

At the Paul Scherrer Institute (PSI) the discharges of radioactive substances without tritium showed a downward trend from 1999 to 2008 of one order of magnitude and are now below 0.1 GBq per year.

3 Environmental Impact

All Swiss nuclear facilities release their liquid discharges into the Rhine catchment area. Three of the NPPs, the ZWILAG waste treatment and interim storage facility and the Paul Scherrer Institute research facility are located on the river Aare, which flows into the river Rhine. One plant (Leibstadt) is located on the river Rhine. As a result of this fact, the environmental monitoring data can only partially be traced back to a single discharge source.

3.1 Concentration of radioisotopes of concern in environmental samples

The results of gamma spectroscopy measurements of sediment in the river Rhine near Basel are shown in figure 3 for the period from 2005 to 2018. The sediments are sampled in traps over a period of 4 weeks. Radionuclides originating from nuclear facilities, like for example Cs-137, Co-58, Co-60 and Mn-54, were observed in traces. The highest concentration values observed are 6.3 Bq/kg for Co-58, due to discharges from the Beznau NPP, and for Cs-137 predominantly due to historical fallout.

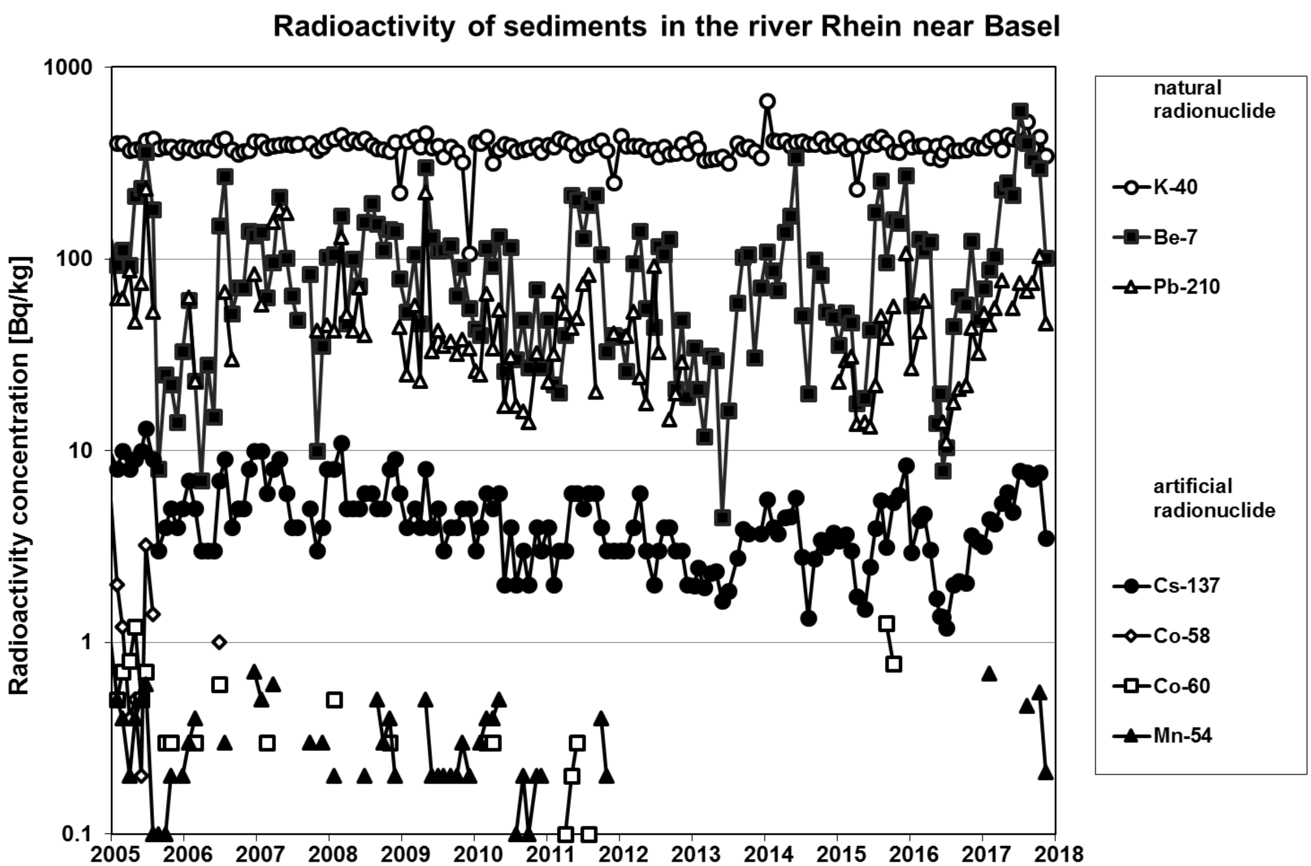

Figure 3: Radioactivity concentration in the sediment of the river Rhein at Pratteln near Basel, downstream of all Swiss nuclear facilities in the catchment area 2005 to 2017. Values below the detection limit are not shown.

3.2 Environmental monitoring program

There are three locations downstream of the NPPs where samples of river water and sediments are taken permanently. The samples are analyzed in a laboratory on a monthly basis.

The first sampling location is at the Hagneck dam, located on the river Aare downstream of the Mühleberg NPP. The second location is at the Klingnau dam, located on the river Aare downstream of the Paul Scherrer Institute, the ZWILAG facility and the Beznau, Gösgen und Mühleberg NPPs. Most of the radioactivity measured in this location is due to the liquid discharges of the Beznau NPP, which is the closest to the sampling point. The liquid discharges of the Gösgen NPP and the Paul Scherrer Institute are so small that their contribution to the radioactivity in the sample is not relevant. The Mühleberg NPP on the other hand is more than 100 km upstream of this sampling point.

The third location is near Basel. It lies on the river Rhine and it is downstream of all the mentioned Swiss nuclear facilities. The radioactivity measured at this location since 2006 is less determined by the liquid discharges of the Beznau NPP (see figure 3).

3.3 System for quality assurance of environmental monitoring

The testing laboratory for analyses in the field of environmental radioactivity of the Federal Office of Public Health and the testing laboratory for radioactivity and dose rate measurements of the Swiss Federal Nuclear Safety Inspectorate are accredited in accordance with ISO/IEC 17025:2005.

3.4 Any relevant information not covered by the requirements specified above

There is no relevant information which is not covered in the previous sections.

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

The submitted data are complete.

4 Radiation Doses to the Public

4.1 Annual effective doses to the reference group caused by liquid discharges

The annual effective doses to a member of the reference group due to liquid discharges of the nuclear power plants, the waste treatment and interim storage facility and the research facility in Switzerland were well below 1 microSv for the last 6 years, as evaluated using the models of the Inspectorate's guideline G14.

4.2 Total exposure (including doses from historical emissions)

The table below shows the yearly doses calculated for individual members of the population in the vicinity of the Swiss nuclear facilities due to liquid and airborne discharges. For the nuclear power plants and ZWILAG doses are determined predominately by the C-14 airborne emission. The doses reported for the Paul Scherrer Institute are mainly associated to emissions of short-lived airborne positron emitters from the accelerator facility (see section F.2.4), which is not classified as a nuclear installation. The reported values lie well below the source-related dose guide value of 0.3 mSv per year.

Article 195 of the Swiss Radiation Protection Ordinance requires that if activity concentrations of artificial radionuclides are detected in the environment leading to an effective dose of more than 10 microSv per year for an exposure pathway and for persons from the population, optimisation measures must then be taken to reduce the discharges. As a consequence, since the discharges are leading to lesser doses, no additional efforts are necessary to reduce radioactive releases and the resulting doses for the population any further from a legal point of view.

Table 3: Total effective dose (including doses from historic emissions) for a person of the reference group living in the vicinity of a Swiss nuclear facility in microSv per year and person, as evaluated using the models of the Inspectorate's guideline G14.

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
Beznau NPP	*< 2*	*< 2*	*< 2*	*< 2*	*< 1*	*< 1*
Gösgen NPP	< 1	< 1	< 2	< 1	< 1	< 1
Leibstadt NPP	< 6	< 7	< 6	< 4	< 4	< 3
Mühleberg NPP	< 5	< 5	< 5	< 5	< 5	< 5
Paul Scherrer Institute	< 7	< 6	< 9	< 7	< 7	< 7
ZWILAG	< 1	< 1	< 1	< 1	< 1	< 1

4.3 Critical group definition

The dose calculations are performed for an individual who is living and working at the place with the highest total dose resulting from immersion, inhalation, ground radiation and ingestion. It is assumed that food e.g. fruits, vegetables, milk and meat which an individual consumes is produced locally. The individual is assumed to cover his needs of drinking water and his consumption of fish from the river downstream of the facility.

4.4 Considered exposure pathways

The following pathways are considered: Immersion from the plume, inhalation, ground radiation and ingestion of fruits, vegetables, milk, meat, fish as well as water drinking from the river downstream of the facility.

4.5 Methodology to assess doses

The methodology to estimate the dose is laid down in the Inspectorate's guideline G14. The models and parameters used in this guideline are taken or derived from international or regulations from other countries for the determination of the radiation exposure caused by radioactive emissions from nuclear facilities, e.g. IAEA, ICRP, the German administrative regulation (Allgemeine Verwaltungsvorschrift).

4.6 Site specific factors to estimate the dose

Site specific factors to estimate the dose are the dispersion factor for the emissions and the mean value of the water flow. The dispersion factor for the emissions was determined by a statistical analysis of the weather parameters measured near the facility.

4.7 Site specific target annual effective dose

The source related dose guide value for a nuclear site is 0.3 mSv per year. In case of relevant superposition of the immission from facilities owned by different licensees, a target annual effective dose is defined; for example, concerning discharges through air or waters, the Paul Scherrer Institute has a target dose of 0.15 mSv per year and the interim storage and waste treatment facility ZWILAG has a target dose of 0.05 mSv per year, while both have a target dose of 0.1 mSv per year for direct radiation.

4.8 System for quality assurance of processes involved in dose estimates

No formal quality assurance system is applied.

4.9 Any relevant information not covered by the requirements specified above

There is no relevant information which is not covered in the previous sections.

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

The submitted data are complete.

5 Summary Evaluation

This report has been produced for the Radioactive Substances Committee of the OSPAR Commission according the guidelines for the submission of information about the application of the BAT principles in nuclear facilities. As a self-assessment the Inspectorate summarizes the following evaluation:

National legislation

The national legislation defines dose guide values/ dose limits, discharge limits, environmental monitoring programs, as well as the national authority responsible for the supervision and the nature of inspection and surveillance. The Federal Act and Ordinance on Radiological Protection, for example, limits the concentration of radioactive substances into the atmosphere and water at locations accessible to the public, requiring the weekly mean value of the concentration to be below the immission limits. The Swiss Ordinance on Contaminants defines maximum concentration values for radionuclides in food and drinking water as an additional restriction. The maximum concentration values basically fulfill the 10 microSv per year concept. The ordinance for ratification of international resolution and recommendations is taking effect since 2000. This legislation requires that the PARCOM-recommendation 91/4 has to be considered at the execution of environmental protection regulations. In 2005 new nuclear energy legislation came into force. The legislation requires the performance of periodic safety reviews by the licensee of nuclear power plants in a time interval of ten years. The periodic safety reviews are evaluated by the Inspectorate. In the frame of the periodic safety review the licensee has to assess the liquid and gaseous discharges of his plant and, at the request of the Inspectorate, to benchmark against the corresponding discharges of similar European reactors. If the discharges of a nuclear power plant are higher than the benchmark, the licensee has to analyze the reasons and to make suggestions to reduce the discharges with a view on the appropriateness of the proposed means.

Annual liquid discharges

All Swiss nuclear facilities with one exception are in the catchment area of the river Rhine. The exception is a nuclear facility for education purpose with no relevant discharges. The total sum of the liquid discharges of radioactive substances excluding tritium from the nuclear facilities in Switzerland shows a downward trend over the last 10 years. The Beznau pressurized water reactors apply cross-flow-nanofiltration of waste water since 2007 and achieved the requested reduction to a value below 1 GBq per year in the liquid discharges excluding tritium, confirming the downward trend observed at the end of the previous reporting period. At the Gösgen pressurized water reactor the discharges of radioactive substances without tritium are the lowest among the European pressurized water reactors. Nevertheless, the Gösgen NPP has further reduced discharges by a factor of 5 from 1994 up to now. The liquid discharges of radioactive substances excluding tritium from the Mühleberg and Leibstadt boiling water reactors show a downward trend. The licensee of Mühleberg had performed a periodical safety review in 2005. The Inspectorate has evaluated this review in depth. As a result the Inspectorate requested from the licensee to reduce the activity without tritium in the liquid discharges to a target setting of 1 GBq per year by 2010. To reach this aim, the licensee studied possibilities for reducing the quantity of wastewater as well as separating different qualities of wastewater for specific treatment. Additionally in September 2015, the licensee has taken a small evaporator in operation. These measures have resulted in a decrease of the released activity from 7 GBq (2007) to 0.1 GBq (2017) per year.

In January 2009, as a result of an inspection the Inspectorate has required the licensee of the incineration and melting plant of the waste treatment and interim storage facility ZWILAG to study the possibilities to reduce the liquid discharges. As a result, in 2010 the licensee started in 2010 to reduce the Cs-137 content in the liquid discharges by sorption with an inorganic ion exchange powder. At the Paul Scherrer Institute research facility the discharges of radioactive substances excluding tritium show a downward trend.

Environmental monitoring program

The environmental monitoring program allows the sampling and detection of concentrations well below the limits for food and drinking water and provides for an independent surveillance of discharges by the federal authorities. Radionuclides originating from nuclear facilities were observed in traces.

The annual effective dose to individuals

The annual effective dose to a member of the critical group caused by the liquid discharges was below 1 microSv for all Swiss nuclear facilities during the years investigated. At the nuclear power plants the total effective doses caused by liquid discharges and emissions are determined predominately by C-14 emissions, at the Paul Scherrer Institute research facility by the emissions from the accelerator. All dose values were below the 10 microSv criterion during the last years.

Conclusion

Based on the above information, the Inspectorate concludes that the BAT/BEP principles are implemented in the Swiss legislation and regulatory practices. Furthermore progress has been made in the application of such principles in the Swiss nuclear facilities with the clearly stated objective of reducing discharges according to the OSPAR strategy on radioactive substances.

Appendix A: Beznau Nuclear Power Plant (KKB)

A.1 Site Characteristics

The Beznau nuclear power plant (KKB) is owned by AXPO Power AG.

The nuclear power plant consists of two virtually identical dual-loop pressurized water reactor units (KKB 1 and KKB 2) built by Westinghouse. KKB 1 started commercial operation in 1969 and KKB 2 in 1971.

The Beznau nuclear power plant is located in Döttingen in the canton Aargau in the North of Switzerland. The Beznau nuclear power plant is cooled by water from the river Aare and it also releases its liquid discharges into the river Aare which belongs to the catchment area of the Rhine.

Each unit has a thermal power of 1130 MW_{th}. As a result of different backfitting measures, the power of both units has improved in the years and the net electrical output since August 2005 is 365 MW_{el} for each unit.

Table A-1: Annual net electrical output 2012-2017 in $GW_{el}h$

	2012	2013	2014	2015	2016	2017
KKB 1	2724.7	3078.5	2920.6	620.9	0.0	0.0
KKB 2	2794.0	2982.0	3053.5	2021.5	3048.4	2813.6
Beznau total	5518.7	6060.5	5974.1	2642.4	3048.4	2813.6

Other relevant information

KKB 1 was out of service from July 2015 till March 2018 due to the safety assessment of the ultrasonic findings at the reactor pressure vessel. KKB 1 could resume operation only after proof was provided, that the inclusions found in the steel of the reactor pressure vessel did not have a negative influence on safety.

A.2 Discharges

A.2.1 Abatement systems

The waste water is collected and treated in batches. The radioactivity in the waste water is reduced by centrifugation and cross-flow-nanofiltration and/or, if necessary, by chemical precipitation. The waste water cleaned this way is sampled, measured and, if the concentration criterions are fulfilled, discharged. In addition, the activity concentration is monitored during the discharge by total gamma counters and if concentration limits are exceeded, the discharge is automatically stopped. In the year 2004 the licensee decided to improve the abatement system by cross-flow-nanofiltration which has gone into operation in the year 2007. The radioactive waste by-products are solidified in the radioactive waste treatment system of the plant.

A.2.2 Efficiency of systems

The chemical precipitation system reduces the concentration of radioactivity in the discharged water by a factor of up to 1000. With the cross-flow-nanofiltration system the concentration is reduced by a factor up to 100. The tritium discharges are not reduced by the abatement systems.

A.2.3 Annual liquid discharges

Beside gamma spectrometry the Beznau NPP determines the activity of tritium in each batch. Sr-90 is checked analyzing monthly samples and alpha-emitters in four samples a year (since the end of 2004). The absolute values of the liquid discharges from both units are shown in tables A-2, A-3 and A-4.
In figure 2 of the main report the discharges of radioactive substances without tritium are plotted as a function of time. The cross-flow-nanofiltration is in full operation since 2007 and the liquid discharges are reduced below 1 GBq per year. For the liquid discharges of tritium, no up or downward trend can be observed.

Table A-2: Liquid discharges without tritium in GBq from Beznau NPP, both units

Isotope	2012	2013	2014	2015	2016	2017
Co-58	1.4E-02	1.1E-02	2.1E-02	2.2E-02	9.5E-03	1.6E-02
Co-60	3.4E-02	6.1E-02	8.3E-02	7.7E-02	5.8E-02	1.1E-01
Zn-65		1.2E-04	4.1E-05	9.6E-05		1.2E-03
Sr-90	4.7E-04	5.5E-04	7.1E-04	7.5E-04	8.6E-04	1.4E-03
Zr-95	3.1E-04	1.7E-05	2.6E-04			
Nb-95	2.0E-05	1.5E-04	1.5E-04		6.7E-05	1.6E-04
Ag-110m	7.4E-03	7.1E-03	1.4E-02	3.5E-03	2.1E-04	5.8E-03
Sb-125	1.7E-02	5.8E-02	4.5E-02	4.5E-02	2.3E-02	2.5E-02
Cs-134	9.2E-03	6.3E-03	3.0E-03	2.5E-03	6.0E-03	1.8E-03
Cs-137	2.4E-01	1.1E-01	1.0E-01	3.2E-01	7.3E-02	4.8E-02
Ce-144		4.7E-04			2.3E-04	
Other isotopes	1.6E-01	1.4E-01	1.4E-01	1.5E-01	2.9E-02	3.1E-02
Total Beta/Gamma without Tritium	4.3E-01	3.9E-01	4.1E-01	6.2E-01	2.0E-01	2.4E-01

Table A-3: Liquid tritium discharges in TBq from KKB 1 and KKB 2

	2012	2013	2014	2015	2016	2017
Tritium	1.2E+01	8.6E+00	1.0E+01	9.9E+00	1.9E+00	6.2E+00

Table A-4: Liquid alpha discharges in GBq from KKB 1 and KKB 2

	2012	2013	2014	2015	2016	2017
Total Alpha	2.4E-05	1.1E-04	9.9E-05	1.1E-04	1.3E-04	1.9E-04

A.2.4 Emissions into air relevant for the marine compartment

Measurements of actual releases of I-129 into the air are not requested by the Inspectorate. The table A-5 shows the C-14 and tritium emissions into the atmosphere by KKB 1 and KKB 2.

Table A-5: C-14 and tritium emission into air in TBq from KKB 1 and KKB 2

	2012	2013	2014	2015	2016	2017
C-14 (CO_2)	3.2E-02	2.0E-02	3.6E-02	2.4E-02	1.8E-02	1.8E-02
Tritium	4.3E-01	5.9E-01	7.5E-01	2.9E-01	3.1E-01	3.1E-01

A.2.5 Quality assurance of retention/data management

The data management system of the Beznau NPP is certified in accordance with ISO 9001:2000 and ISO 14001:1996.

A.2.6 Site specific target discharge data

The Beznau NPP site specific target for liquid discharge without Tritium is to be below 1 % of the discharge limit given in the license.

A.2.7 Any relevant information not covered by the requirements specified above

There is no relevant information which is not covered by the previous sections.

A.2.8 Explanations for lack of data or failure to meet BAT/BEP indicators, ongoing and planned activities

The submitted data are complete.

A.3 Environmental Impact

The information is given in chapter 3 of the main report.

A.4 Radiation Doses to the Public

The information is given in chapter 4 of the main report.

Appendix B: Gösgen Nuclear Power Plant (KKG)

B.1 Site Characteristics

The Gösgen nuclear power plant is owned by the Kernkraftwerk Gösgen-Däniken AG.

The nuclear power plant is a 3-loop pressurized water reactor, built by Kraftwerk Union AG (KWU, now Framatome). The plant started commercial operation in 1979.

The Gösgen nuclear power plant is located in Däniken in the canton Solothurn in the North of Switzerland. The plant has a wet cooling tower and releases its liquid discharges into the river Aare which belongs to the catchment area of the river Rhine.

The Gösgen NPP has a thermal power of 3002 MW_{th} and a net electrical output of 1010 MW_{el}.

Table B-1: Annual net electrical output 2012-2017 in $GW_{el}h$

	2012	2013	2014	2015	2016	2017
Gösgen NPP	8073.9	6410.2	8022.0	7971.2	8167.3	8084.3

Other relevant information

At Gösgen NPP site, a building for the wet storage of spent fuel elements is in operation since 2008. The waste water system of the new storage building is integrated to the existing discharge system.

B.2 Discharges

B.2.1 Abatement systems

The waste water is collected and treated in batches. The radioactivity in the waste water is reduced by evaporation. The distillate is sampled, measured and, if the concentration criterions are fulfilled, discharged in batches. In addition the concentration of radioactivity is monitored during the discharge by total gamma counters and, if concentration limits are exceeded, the discharge is automatically stopped. The residues are conditioned with bitumen in the radioactive waste treatment system of the plant.

B.2.2 Efficiency of systems

The water evaporation reduces the concentration of radioactivity in the discharged water by a factor of 100 up to 10’000. The tritium discharges are not reduced by the abatement system.

B.2.3 Annual liquid discharges

Beside gamma spectrometry KKG determines the activity of tritium, Sr-90 and alpha-emitters by analyzing monthly samples. The absolute values of the liquid discharges from KKG are shown in tables B-2, B-3 and B-4.

In the figure 2 in the main report, the discharges of radioactive substances without tritium are plotted as a function of time. At the Gösgen NPP the discharges of radioactive substances without tritium are the lowest among the European pressurized water reactors. Nevertheless the Gösgen NPP has further reduced discharges by a factor of 5 from 1994 up to now. For the liquid discharges of tritium, no up or downward trend can be observed.

Table B-2: Liquid discharges without tritium in GBq from KKG

Isotope	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Co-58						4.4E-05
Co-60	1.0E-03	9.8E-04	2.9E-04	8.4E-05	7.8E-05	
Sr-90				9.4E-04		
Zr/Nb-95			1.0E-04			
RU-106			4.1E-04			
Cs-134	1.2E-03					
Cs-137	3.2E-03					5.6E-05
Other isotopes	5.7E-03	3.3E-03	1.5E-03	2.8E-03	2.4E-03	2.6E-03
Total Beta/Gamma without Tritium	1.1E-02	4.3E-03	2.3E-03	3.8E-03	2.5E-03	2.7E-03

Table B-3: Liquid tritium discharges in TBq from KKG

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
Tritium	1.4E+01	1.8E+01	1.5E+01	1.4E+01	1.2E+01	1.9E+01

Table B-4 Liquid alpha discharges in GBq from KKG

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
Total Alpha	1.3E-04	1.3E-04	1.9E-04	1.5E-04	2.1E-04	1.2E-04

B.2.4 Emissions into air relevant for the marine compartment

Measurements of actual releases of I-129 into the air are not requested by the Inspectorate. The table B-5 shows the C-14 and tritium emissions into the atmosphere by KKG.

Table B-5: C-14 and tritium emission into air in TBq from KKG

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
C-14 (CO_2)	4.1E-02	8.4E-02	1.1E-01	4.6E-02	5.2E-02	4.4E-02
Tritium	5.4E-01	6.0E-01	5.1E-01	4.8E-01	4.4E-01	5.9E-01

B.2.5 Quality assurance of retention/data management

The data management system of KKG is certified in accordance with ISO 9001:2015, ISO 14001:2015 and OHSAS 18001:2007.

B.2.6 Site specific target discharge data

KKG has formulated as internal goal that of keeping the environmental impact below 0.01 mSv per year and person.

B.2.7 Any relevant information not covered by the requirements specified above

There is no relevant information which is not covered by the previous sections.

B.2.8 Explanations for lack of data or failure to meet BAT/BEP indicators, ongoing and planned activities

The submitted data are complete.

B.3 Environmental Impact

The information is given in chapter 3 of the main report.

B.4 Radiation Doses to the Public

The information is given in chapter 4 of the main report.

Appendix C: Leibstadt Nuclear Power Plant (KKL)

C.1 Site Characteristics

The Leibstadt nuclear power plant is owned by the Kernkraftwerk Leibstadt AG

The nuclear power plant is a boiling water reactor (BWR), built by General Electric. KKL started commercial operation in 1984.

The Leibstadt nuclear power plant is located in the Leibstadt village in the canton Aargau in the North of Switzerland on the German border. The plant has a wet cooling tower and releases its liquid discharges into the river Rhine.

KKL has a thermal power of 3600 MW_{th} and a net electrical output of 1220 MW_{el}.

Table C-1: Annual net electrical output 2012-2017 in $GW_{el}h$

	2012	2013	2014	2015	2016	2017
Leibstadt NPP	7881.3	9692.0	9458.0	8589.5	6075.4	5618.8

Other relevant information

The years 2016 and 2017 were marked by local anomalies on claddings of high power fuel assemblies of a specific type. This – even though the fuel rod integrity was not affected – resulted in extended outage periods for enhanced fuel assembly inspections and modes of operation with reduced reactor power.

C.2 Discharges

C.2.1 Abatement systems

The waste water is collected and treated in batches. The radioactivity in the waste water is reduced by centrifugation and evaporation. The distillate is sampled, measured and, if the concentration criterions are fulfilled, discharged in batches. In addition, the concentration of radioactivity is monitored during the discharge by total gamma counters and, if concentration limits are exceeded, the discharge is automatically stopped.

C.2.2 Efficiency of systems

The decontamination factor of the evaporator is of the order of 1’000 up to 10’000 (ratio of concentration in feed liquid to that of the distillate). The tritium discharges are not reduced by the abatement system.

C.2.3 Annual liquid discharges

Beside gamma spectrometry, KKL determines the activity of tritium, Sr-90 and alpha-emitters by analyzing quarterly samples. The absolute values of the liquid discharges from KKL are shown in tables C-2, C-3 and C-4.

In figure 2 in the main report, the discharges of radioactive substances without tritium are plotted as a function of time. At the Leibstadt NPP a downward trend can be observed and the discharges of radioactive substances without tritium are low. No up or downward trend can be observed for the liquid discharges of tritium, with one exception: as of 2015, extended periods of forced shutdowns have resulted in considerably lower emissions of tritium.

Table C-2: Liquid discharges without tritium in GBq from KKL

Isotope	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Co-58	2.7E-03	1.3E-03	3.2E-03	3.0E-03	1.5E-03	2.2E-03
Co-60	8.2E-02	4.4E-02	1.0E-01	1.1E-01	1.0E-01	1.5E-01
Zn-65	2.7E-02	6.1E-03	1.0E-02	8.4E-03	6.5E-3	3.6E-03
Sb-125		1.1E-03	1.1E-02	1.3E-03		3.4E-04
Cs-134			2.4E-04	2.6E-04		
Cs-137		9.7E-04	7.5E-04	2.6E-03	5.0E-4	6.6E-04
Other isotopes	1.6E-02	7.7E-03	3.5E-02	2.4E-02	1.1E-02	1.3E-02
Total Beta/Gamma without Tritium	1.3E-01	6.1E-02	1.6E-01	1.5E-01	1.2E-01	1.7E-01

Table C-3: Liquid tritium discharges in TBq from KKL

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
Tritium	1.4E+00	1.4E+00	1.3E+00	7.5E-01	4.4E-01	4.2E-01

Table C-4: Liquid alpha discharges in GBq from KKL

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
Total Alpha	3.2E-04	4.2E-04	1.5E-04	3.5E-04	2.4E-04	3.1E-05

C.2.4 Emissions into air relevant for the marine compartment

Measurements of actual releases of I-129 into the air are not requested by the Inspectorate. The table C-5 shows the C-14 and tritium emissions into the atmosphere by KKL.

Table C-5: C-14 and tritium emission into air in TBq from KKL

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
C-14 (CO_2)	6.4E-01	7.7E-01	6.3E-01	4.2E-01	3.6E-01	3.2E-01
Tritium	1.2E+00	1.3E+00	1.2E+00	6.9E-01	4.4E-01	2.8E-01

C.2.5 Quality assurance of retention/data management

The data management system of KKL is certified in accordance with ISO 9001:2000.

C.2.6 Site specific target discharge data

KKL has set as the site specific target for liquid discharges to be below the limits given in the license.

C.2.7 Any relevant information not covered by the requirements specified above

There is no relevant information which is not covered by the previous sections.

C.2.8 Explanations for lack of data or failure to meet BAT/BEP indicators, ongoing and planned activities

The submitted data are complete.

C.3 Environmental Impact

The information is given in chapter 3 of the main report.

C.4 Radiation Doses to the Public

The information is given in chapter 4 of the main report.

Appendix D: Mühleberg Nuclear Power Plant (KKM)

D.1 Site Characteristics

The Mühleberg nuclear power plant is owned by the BKW Energie AG.

The Mühleberg nuclear power plant is a boiling water reactor, built by General Electric. It started commercial operation in 1972.

The Mühleberg nuclear power plant is located in the Mühleberg village in the canton Bern. The Mühleberg NPP is cooled by water from the river Aare and it releases its liquid discharges into the river Aare which belongs to the catchment area of the Rhine.

KKM has a thermal capacity of 1’097 MWth and a net electrical output of 373 MWel.

Table D-1: Annual net electrical output 2012-2017 in $GW_{el}h$

	2012	2013	2014	2015	2016	2017
Mühleberg NPP	3002.7	2954.7	3040.1	2939.9	2946.2	2998.2

Other relevant information

The licensee of Mühleberg had performed a periodical safety review in 2005. The Inspectorate has evaluated this review. As a result, the Inspectorate requested from the licensee to reduce the activity excluding tritium in the liquid discharges to a target setting of 1 GBq per year by 2010. To reach this aim, the licensee studied possibilities for reducing the quantity of wastewater as well as separating different qualities of wastewater for specific treatment. Additionally in September 2015, the licensee has taken a small evaporator in operation. These measures has resulted in a decrease of the released activity from 7 GBq (2007) to 0.1 GBq (2017) per year.

In 2013 the licensee of Mühleberg decided to shut down the plant at the end of 2019. On 18 December 2015, the licensee submitted a formal application for the decommissioning to the licensing authority, which was assessed by the Inspectorate in August 2017. As a result, the Inspectorate proposed a reduction of the liquid discharge limits by a factor of 10 compared to the power operation phase. The target setting of 1 GBq per year is also maintained. Based on the assessments of ENSI and other authorities, the Federal Department of the Environment, Transport, Energy and Communications (DETEC) issued the corresponding decommissioning order on 20 June 2018, in which the Inspectorate's proposals regarding the reduction of the levy limits were adopted.

D.2 Discharges

D.2.1 Abatement systems

The waste water is collected and treated in batches. The radioactivity in the waste water is reduced by centrifugation, ion exchange and evaporation. The waste water cleaned by this mean is sampled, measured and, if the concentration criterions are fulfilled, discharged in batches. In addition, the concentration of radioactivity is monitored during the discharge by total gamma counters and if concentration limits are exceeded, the discharge is automatically stopped. The radioactive waste by-products are solidified in the radioactive waste treatment system of the plant.

D.2.2 Efficiency of systems

The centrifugation, ion exchange system and evaporation reduces the concentration of radioactivity in the discharged water by a factor between 100 and up to 10'000. The tritium discharges are not reduced by the abatement system.

D.2.3 Annual liquid discharges

Beside gamma spectrometry Mühleberg NPP determines the activity of tritium, Sr-90 and since 2002 alpha-emitters by analyzing quarterly samples. The absolute values of the liquid discharges from KKM are shown in tables D-2, D-3 and D-4.
In figure 2 in the main report, the discharges of radioactive substances without tritium are plotted as a function of time. At the Mühleberg NPP a downward trend can be observed.

Table D-2: Liquid discharges without tritium in GBq from KKM

Isotope	2012	2013	2014	2015	2016	2017
Co-58	3.5E-01	5.0E-01	7.4E-02	1.1E-01	4.4E-02	1.4E-02
Co-60	1.3E+00	1.5E+00	4.8E-01	7.4E-01	1.3E-01	5.9E-02
Zn-65	5.7E-02	6.8E-02	2.0E-02	5.5E-02	7.2E-03	3.1E-03
Sr-90	6.1E-04	5.6E-04	6.3E-04	5.1E-04	5.0E-04	2.6E-04
Zr/Nb-95	1.5E-03	8.8E-04	4.8E-04			
Ag-110m	4.5E-04	6.6E-04	1.6E-03	2.4E-04	9.4E-04	
Sb-125		4.0E-03	6.1E-04			
Cs-134					9.6E-05	
Cs-137	1.1E-02	9.7E-03	6.3E-03	2.8E-03	3.9E-03	1.7E-03
Other isotopes	1.3E+00	6.3E-01	1.7E-01	1.9E-01	7.3E-02	3.2E-02
Total Beta/Gamma without Tritium	3.0E+00	2.7E+00	7.5E-01	1.1E+00	2.6E-01	1.1E-01

Table D-3: Liquid tritium discharges in TBq from KKM

	2012	2013	2014	2015	2016	2017
Tritium	2.4E-01	1.7E-01	9E-02	3.1E-01	1.1E-01	1.2E-01

Table D-4: Liquid alpha discharges in GBq from KKM

	2012	2013	2014	2015	2016	2017
Total Alpha	5.3E-05	2.6E-05	1.7E-05	1.2E-04	1.4E-05	1.2E-05

D.2.4 Emissions into air relevant for the marine compartment

Measurements of actual releases of I-129 into the air are not requested by the Inspectorate. The table D-5 shows the C-14 and tritium emissions into the atmosphere by KKM.

Table D-5: C-14 and tritium emission into air in TBq from KKM

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
Isotope	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
C-14 (CO_2)	3.2E-01	3.7E-01	3.4E-01	3.3E-01	3.8E-01	3.6E-01
Tritium	1.2E-02	2.1E-02	2.0E-02	3.9E-02	2.3E-02	3.4E-02

D.2.5 Quality assurance of retention/data management

The data management system of KKM is certified in accordance with ISO 9001:2008 and ISO 14001:2004 and OHSAS 18001:2007.

D.2.6 Site specific target discharge data

KKM has set a site specific target for liquid discharges to be below the limits given in the license.

D.2.7 Any relevant information not covered by the requirements specified above

There is no relevant information which is not covered by the previous sections.

D.2.8 Explanations for lack of data or failure to meet BAT/BEP indicators, ongoing and planned activities

The submitted data are complete.

D.3 Environmental Impact

The information is given in chapter 3 of the main report.

D.4 Radiation Doses to the Public

The information is given in chapter 4 of the main report.

Appendix E: Waste Treatment and Interim Storage (ZWILAG)

E.1 Site Characteristics

The ZWILAG waste treatment and interim storage facility is owned by the four Swiss nuclear power plant licensees.

Low and medium-level radioactive waste from Swiss nuclear power plants as well as from medicine, industry and research is processed by a conditioning and an incineration and melting plant in ZWILAG. The site also provides interim storage for all types of radioactive waste and spent fuel assemblies from Swiss nuclear power plants.

The ZWILAG is located next to the Paul Scherer Institute near the village Würenlingen in the canton Aargau. It releases its liquid discharges into the river Aare which belongs to the catchment area of the Rhine.

The waste treatment and interim storage facility ZWILAG in Würenlingen was put in operation step by step. First the interim storage facility started operation in 2001. The incineration and melting plant started in 2004, after several inactive tests, with the treatment of a series with low-level radioactive waste. In the years from 2001 to 2004 the emissions into the air and discharges into the river Aare were very low and are therefore not reported. Switzerland started reporting on ZWILAG to OSPAR in 2005.

Other relevant information

Since 2005 when the incineration and melting plant was put in operation the liquid discharges of radioactive substances without tritium increased up to a value of 3.5 GBq in 2009. The reason for this increase can be found in the incineration and melting plant. The radioactive waste from the nuclear power plants contains plastic. Carbon dioxide and steam are therefore produced during incineration. The carbon dioxide, the steam and the easily volatile Cs-137 get in the scrubbers of the flue gas cleaning system. There they form cesium chloride, which cannot be removed from wastewater by simple chemical or physical methods. In January 2009, as a result of an inspection, the Inspectorate has required the licensee to study the possibilities to reduce the activities in the liquid discharges. As a result of this study the licensee reduced the Cs-137 content in the liquid discharges by sorption with an inorganic ion exchange powder.

E.2 Discharges

E.2.1 Abatement systems

Installed systems:

The waste water is collected and treated in batches. Methods to reduce radioactivity in the waste water include evaporation, centrifugation and sorption with an element specific inorganic ion exchange powder. To the evaporation system belongs also an ion exchanger to process the distillate. The waste water cleaned by this means is sampled, measured and, if the concentration criterions are fulfilled, discharged in batches. In addition, the concentration of radioactivity is monitored during the discharge by total gamma counters and if concentration limits are exceeded, the discharge is automatically stopped. The radioactive waste by-products are solidified in the radioactive waste treatment system of the plant.

E.2.2 Efficiency of systems

With the evaporation system the concentration of radioactivity in the discharged water can be reduced by a factor of 100 to 10’000. By sorption with an inorganic ion exchange powder the Cs-137 content in the liquid discharges can be reduced by a factor of 100. The tritium discharges are not reduced by the abatement system.

E.2.3 Annual liquid discharges

Beside gamma spectrometry ZWILAG determines the activity of tritium, Sr-90 and alpha-emitters by analyzing composite samples, which are composed of aliquot parts of the individual discharges within a quarter of the year. The absolute values of the liquid discharges from ZWILAG are shown in tables E-1, E-2 and E-3.
In figure 2 in the main report, the discharges of radioactive substances without tritium are plotted as a function of time. The discharges of radioactive substances excluding tritium increased up to a value of 3.5 GBq in 2009. In January 2009 the Inspectorate has required the licensee to study the possibilities to reduce the activities in the liquid discharges. As a result of this study the licensee reduces the Cs-137 content in the liquid discharges since 2010 by sorption with an inorganic ion exchange powder. The discharged activities decreased to a value of 0.48 GBq in 2017.

Table E-1: Liquid discharges excluding tritium in GBq from ZWILAG

Isotope	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Co-60	1.5E-03	9.9E-03	1.4E-02	8.4E-03	7.6E-03	1.2E-02
Ru-106		5.5E-03	6.2E-04			
Sb-125	1.6E-04	5.0E-03	1.5E-02	2.4E-02	8.3E-03	3.0E-02
Cs-134	5.1E-03	3.7E-03	2.2E-02	1.2E-02	1.8E-03	1.2E-02
Cs-137	1.8E-01	3.4E-01	5.6E-01	4.3E-01	3.7E-01	4.2E-01
Other isotopes	1.3E-03	6.0E-03	1.5E-03	2.6E-02	2.0E-03	6.3E-03
Total Beta/Gamma without Tritium	1.9E-01	3.7E-01	6.1E-01	5.0E-01	3.9E-01	4.8E-01

Table E-2: Liquid tritium discharges in TBq from ZWILAG

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
Tritium	3.1E-02	1.8E-03	2.4E-03	9.0E-4	3.2E-03	2.3E-02

Table E-3: Liquid alpha discharges in GBq from ZWILAG

	2012	2013	2014	2015	2016	2017
Total Alpha	2.2E-06	2.6E-06	1.7E-05	3.9E-05	3.2E-06	2.8E-06

E.2.4 Emissions into air relevant for the marine compartment

Measurements of actual releases of I-129 into air are not requested by the Inspectorate. Table E-4 shows the C-14 and tritium emissions from ZWILAG.

Table E-4: C-14 and tritium emission into air in TBq from ZWILAG

	2012	2013	2014	2015	2016	2017
C-14 (CO_2)	4.5E-04	8.3E-05	3.0E-04		4.7E-05	2.0E-04
Tritium	8.8E-03	1.6E-03	1.1E-03	7.9E-04	1.8E-02	4.2E-02

E.2.5 Quality assurance of retention/data management

The data management system of ZWILAG based is certified in accordance with ISO 9001:2008.

E.2.6 Site specific target discharge data

ZWILAG has set as site specific target for liquid discharges to be below the limits given in the license.

E.2.7 Any relevant information not covered by the requirements specified above

There is no relevant information which is not covered by the previous sections.

E.2.8 Explanations for lack of data or failure to meet BAT/BEP indicators, ongoing and planned activities

The submitted data are complete.

E.3 Environmental Impact

The information is given in chapter 3 of the main report.

E.4 Radiation Doses to the Public

The information is given in chapter 4 of the main report.

Appendix F: Paul Scherrer Institute (PSI)

F.1 Site Characteristics

The Paul Scherrer Institute was founded in 1988 and is the largest research centre for natural and engineering sciences within Switzerland, with its research activities concentrated on three main subject areas: *Matter and Materials*, *Energy and the Environment* and *Human Health*. The institute's facilities include various laboratories, facilities for the medical application of radiation, the accelerator installations with the SINQ spallation neutron source, the free-electron X-ray laser SwissFEL, and the synchrotron light source. The following facilities are under the regime of the nuclear energy legislation: the HOTLAB with its laboratories and hot cells, the waste treatment facilities, the federal interim storage facility BZL and three former research reactors in decommissioning state.

The Paul Scherrer Institute is located between the villages of Villigen and Würenlingen in the canton Aargau in the North of Switzerland. The PSI releases its liquid discharges into the river Aare which belongs to the catchment area of the Rhine.

F.2 Discharges

F.2.1 Abatement systems

The waste water is collected and treated continuously. The radioactivity in the waste water is reduced by diffusion through membranes due to pressure difference. The waste water cleaned in this way is sampled, analyzed for gamma and total alpha and discharged in batches. In addition, during discharge the concentration of radioactivity is monitored by total gamma counters and, if concentration limits are exceeded, the discharge is automatically stopped. The radioactive waste by-products are solidified at the radioactive waste treatment system of the institute.

F.2.2 Efficiency of systems

The described system reduces the concentration of the radioactivity in the discharged water at least by a factor of 1'000. The tritium discharges are not reduced by the abatement system.

F.2.3 Annual liquid discharges

Beside gamma spectrometry the PSI has to determine the activity of Tritium, Sr-90 and alpha-emitters by analyzing quarterly samples. The absolute values of the liquid discharges from PSI are shown for the last six years in the tables F-1 and F-2.

In figure 2 in the main report, the discharges of radioactive substances without tritium are plotted as a function of time. The discharges of radioactive substances excluding tritium show a downward trend by one order of magnitude form 2007 to 2012.

Table F-1: Liquid discharges excluding tritium in GBq from PSI

Isotope	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Be-7	4.2E-03	1.4E-04	1.0E-03	1.8E-04	1.1E-02	1.4E-02
Na-22	1.5E-04	9.2E-05	3.6E-04	2.6E-04	8.1E-05	6.4E-05
S-35			1.3E-02	1.8E-02		
Sc-44	1.7E-05					1.3E-05
Sc-46			1.4E-05	5.9E-06	7.0E-06	9.9E-05
Ca-47				9.0E-05		
Sc-47		7.2E-04	1.4E-04	4.1E-04	7.1E-04	
Sc-48					6.3E-06	
V-48					1.0E-05	
Ti-44	1.7E-05					
Mn-54	2.1E-04	6.2E-05	5.6E-04	5.6E-05	4.2E-04	2.3E-03
Co-56			2.9E-05	4.1E-06	1.4E-05	1.7E-05
Co-57	1.5E-05	2.3E-05	1.6E-04	1.5E-05	3.1E-05	1.6E-04
Co-58		2.4E-06	2.8E-05	2.4E-06	3.5E-05	7.0E-05
Co-60	5.5E-04	8.0E-04	1.4E-02	7.6E-03	7.2E-04	7.8E-04
Zn-65	2.6E-05					1.0E-05
Ga-67	2.8E-04					
Se-75						2.4E-05
Rb-82m						1.6E-05
Rb-83					9.8E-06	5.0E-05
Zr-88	2.5E-04					
Y-88	6.3E-05			2.4E-06	7.2E-06	2.4E-05
Sr-85					3.9E-06	
Sr-89					7.2E-06	
Sr-90/Y90	3.5E-04	1.3E-02	9.6E-02	3.8E-02	1.2E-03	
Ag-110m	1.1E-05	3.0E-05	1.7E-05	5.3E-05		3.2E-06
In-111	2.6E-05	3.1E-05	1.4E-04		1.2E-04	8.9E-05
Sb-124					1.1E-04	3.4E-04
Sb-125		5.2E-05				
I-125	3.3E-03	1.2E-03	5.6E-04	9.5E-05		
Ag-110m	1.1E-05	3.0E-05	1.7E-05	5.3E-05		3.2E-06
In-111	2.6E-05	3.1E-05	1.4E-04		1.2E-04	8.9E-05

Sb-124					1.1E-04	3.4E-04
Isotope	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Sb-125		5.2E-05				
I-125	3.3E-03	1.2E-03	5.6E-04	9.5E-05		
I-131	5.9E-04					
Ba-133				4.7E-06		2.9E-04
Cs-134	2.5E-04	4.9E-05	3.7E-05	2.5E-05	5.0E-05	1.3E-05
Cs-137	6.3E-03	3.5E-02	1.4E-01	5.9E-02	1.3E-02	5.5E-03
Ce-141					7.9E-06	
Gd-149					7.1E-05	
Sm-153						6.8E-06
Tb-155			6.4E-05			1.0E-05
Tb-160				3.7E-05	1.8E-05	
Tb-161	6.1E-04	2.5E-03	9.0E-04	5.3E-03	2.8E-05	2.7E-03
Lu-172	1.8E-05		6.3E-05	1.3E-04	2.1E-05	2.1E-04
Lu-173			4.6E-05	1.5E-04		8.2E-05
Lu-177	1.3E-02	2.2E-02	3.0E-02	3.9E-02	3.5E-02	1.7E-02
Os-185	8.8E-06					3.7E-05
Au-195	3.1E-04	4.4E-04				1.7E-04
Bi-207	6.4E-06	2.1E-05	1.2E-05	2.1E-05	5.6E-06	2.7E-05
Po-208	1.3E-05					
Total Beta/ Gamma activity without Tritium	3.1E-02	7.6E-02	3.0E-01	1.7E-01	6.3E-02	4.4E-02

Table F-2: Liquid tritium discharges in TBq from PSI

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
Tritium	1.2E-02	8.0E-02	2.2E+00	6.2E-01	1.9E-01	1.1E-01

Table F-3: Liquid alpha discharges in GBq from PSI

	2012	**2013**	**2014**	**2015**	**2016**	**2017**
Total Alpha	1.4E-04	1.9E-04	4.7E-05	2.3E-04	1.3E-05	7.9E-05

F.2.4 Emissions into air relevant for the marine compartment

Measurements of actual releases of I-129 into air are not requested by the Inspectorate. Table F-4 shows the C-14 and tritium emissions from PSI. The C-14 content within the emissions into the air from the waste treatment facilities and the federal interim storage facility BZL are being measured since 2016 following a request from the Inspectorate. Further radioisotopes with short half-lives produced by the accelerators (which are not classified as nuclear installations) as side effect, like C-11, N-13, O-15 are monitored during the release into the atmosphere. These emissions dominate the doses reported in Table 3.

Table F-4: C-14 and Tritium emissions into air in TBq from PSI for the last six years

	2012	2013	2014	2015	2016	2017
C-14 (CO_2)					2.2E-04	1.5E-04
Tritium	1.1E+00	1.3E+00	1.8E+00	1.1E+00	1.5E+00	2.5E+00

F.2.5 Quality assurance of retention/data management

The data management system of PSI is accredited in accordance with ISO 17025:2005.

F.2.6 Site specific target discharge data

PSI has set as site specific target for liquid discharges to be below the limits given in the license.

F.2.7 Any relevant information not covered by the requirements specified above

There is no relevant information which is not covered by the previous sections.

F.2.8 Explanations for lack of data or failure to meet BAT/BEP indicators, ongoing and planned activities

The submitted data are complete.

F.3 Environmental Impact

The information is given in chapter 3 of the main report.

F.4 Radiation Doses to the Public

The information is given in chapter 4 of the main report.

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